THE

THEOLOGICAL,

PHILOSOPHICAL AND MISCELLANEOUS

WORKS

OF THE

REV. WILLIAM JONES, M.A. F.R.S.

IN TWELVE VOLUMES.

TO WHICH IS PREFIXED,

A SHORT ACCOUNT

OF HIS

LIFE AND WRITINGS.

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CONTENTS

OF THE

EIGHTH VOLUME.

AN

ESSAY

ON

THE FIRST PRINCIPLES

OF

NATURAL PHILOSOPHY:

WHEREIN

The Use of NATURAL MEANS, or SECOND CAUSES, in the Economy of the Material World, is demonstrated from REASON, EXPERIMENTS of various Kinds, and the TESTIMONY of ANTIQUITY.

IN FOUR BOOKS,

ILLUSTRATED WITH COPPERPLATES.

Και σωφρων ημαρτε, και αφρονι πολλακι δοξα Αττετο. *Theog.*

Multa renascentur quæ jam cecidere. *Hor.*

CONTENTS.

BOOK I.

Of the Mechanism of Nature.

BOOK II.

Attraction and Gravity considered at large.

BOOK

BOOK III.

Of a *Vacuum* in the Heavens, and between the Parts of Bodies: with an Experimental Inquiry into the Physical Causes of *Cohesion* and *Repulsion*.

BOOK

BOOK IV.

The Judgment of Antiquity on the System of Nature: together with the Sentiments of some Modern Authors of the best repute.

POSTSCRIPT.

AN ESSAY,

&c.

BOOK I.

On the Mechanism of Nature; or the Use of natural means in the producing of physical effects.

CHAP. I.

The Introduction. Some occasional reflections on the prejudices of Philosophers. Apology for the Author, with an account of his design. Two different systems of Philosophy briefly explained.

GOD having created the world for the benefit of all mankind, every man has a natural liberty of inquiring into the ſtructure of it, and examining the various motions that appear in it, with their several

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dependences, circumstances, and causes: a study highly commendable, if confidered only as an inexhauftible fund of innocent amusement, but worthy of a better name, when applied to its proper use: for if it be not our own fault, we may, *out of the good things that are seen, know him that is;* and, *by considering the works,* be led to *acknowlege* the power, goodness, and unspeakable wisdom of the *workmaster.*

In this inquiry, though a man may reap many advantages by seeing with the eyes of others, who could see farther than himself, and is greatly to be blamed if he does not make use of the opportunity; there is certainly no law that obliges him to keep his eyes fhut, where his own safety and satisfaction require him to open them. The constitution of the world, together with the powers, causes, or principles upon which the operations of nature depend, being matters of fact, and not points of speculation, it is *evidence* alone that can lead us to any rational determination.

My design at present, therefore, is to collect as much of this evidence as the case can reasonably be thought to require, and lay it before the public, without any regard to

to the systematical reasonings, or reputed authority, of this or that philosopher in particular. In the prosecution of this design, I shall endeavour to express my mind with freedom and impartiality, as a man ought in conscience to do, who has no private ends to serve, and does not desire that the value of what he has written ſhould be determined by the favour of his friends, but rather that his enemies, if he has any, would rigorouſly compare it with their own observation and experience.

If we are not free from those vulgar prejudices—that it is a great misfortune to be singular—that the multitude (who have been always changing) must necessarily be in the right—and that the *last* writer, who has obtained a name in any subject, is to be followed implicitly in every thing he has propounded; we ſhall be afraid to *inquire*, and to endeavour to advance the progress of true and useful knowlege, as we all profess to do, and all ought to do; but shall rather fall upon the fruitless labour of accommodating every new discovery to the principles we have already received, looking at the same time with a suspicious eye on every writer, who, with regard to any particular article, would

turn us out of the beaten track. An ancient maxim of the once celebrated Thomas Aquinas —*Cave ab illo qui unicum librum legit*, deserves to be considered by all those, who dare not venture abroad in quest of truth, but behind the back of their tutor: in which situation they may possibly see so much of *him*, as to be able to see nothing else.

It will readily be granted, I suppose, that such a practice as this is very childish and absurd, provided the observation be applied only to the prejudices which once reigned in favour of Aristotle, Descartes, or the Chymists: yet it so happens, that if an author comes home to his own times, and ventures to look into any of the pretensions of the present age, he is in danger of being assaulted by all that meet with him, and generally with the greatest vehemence by those who are the most superficial in their knowledge.

This consideration, I frankly confess, hath sometimes had so much weight, and appeared so formidable to me, that I have been almost tempted to throw my pen into the fire, rather than employ it against any current opinion. A sincere love, however, of the science of nature, and a confirmed persuasion both of its usefulness and its importance,

portance, ought to prevail against these difficulties; and they have prevailed with me, to try, in the first place, if I can dispel some of that learned darkness with which the subject has been overspread, and open the way to a better understanding of it.

And here I cannot but reckon it a great advantage to truth, though it is none at all to myself, that, in perusing the following sheets, the reader is in no danger of being dazzled or misled by the influence of a name so inconsiderable as that of the author; who has no popular prejudices to appeal to, and cannot expect to be heard upon any considerations, but the importance of the matter, the clearness of the facts, and the strength of the arguments he has to propose.

Why this attempt should give offence to any person, he cannot well imagine. For, if we divide the world of Philosophers into two parties, some of whom are influenced by an undissembled zeal for the Christian faith, while others are not ashamed to declare that they have no religion at all; the former, I presume, can have no good objection to any phyfical disquisition, which is conducted with submission and modesty; it being impossible that true religion and true philosophy

should be at variance; because He who created all those works, which are the proper objects of natural philosophy, was also the author of divine revelation: and God is not divided against himself. And unless it were in my power to point out some particulars, in which this disquisition may prove to be of service to religion, I should be able to give but a poor account of those many hours, which I have been obliged to borrow from that profession and study, to which the providence of God hath more immediately called me. As to the latter, they, I think, who are so forward to tell us, they have rejected all human authority, and can *think freely* in matters of religion, will not be very consistent with themselves, if they are angry with me for thinking as freely in matters of philosophy.

This ought to be remembered likewise for the satisfaction of all parties, that if the method of explaining natural effects, now in vogue amongst us, be established on sufficient proof, or rather, as it is commonly reported, on undeniable demonstration; all that I shall occasionally offer against it, though it may puzzle some superficial readers unacquainted with the subject, will not

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weaken it in the opinion of any man of true learning and judgment. If it be not established on sufficient proof, what harm will there be in disbelieving it? We shall then be at liberty to turn our thoughts another way, and may be looking out with some better prospect of success. And as it appears, to me at least, that no *physical effect* is really explained or understood, unless it is deduced from a *physical cause*, the existence and operation of which can be experimentally demonstrated; I shall humbly endeavour to shew, that the modern philosophy, although it has carried natural knowlege to a great height in some respects, can furnish no sound arguments or real objections against the *mechanism* of the natural world; and that in every thing it has advanced against this mechanism, it doth itself proceed upon such principles as are arbitrary, and unsupported by any evidence that is truly philosophical or physical. These I know are very bold assertions; but if the reader will only prevail with himself to bear with me for a while, and have a little patience, he may perhaps find some reasons, more considerable than he is aware of, for being of the same opinion.

Every person, who makes use of his senses, must needs be convinced, that the matter comprehended within this visible world is full of motion; and the learned have very greatly doubted, by what means, and after what manner, this motion is supported and preserved. Some of them, according to their own accounts, begin with the two principles of *matter* and a *void space*. To their matter they give this capital *Law*, that if once moved, it shall continue in motion, because it has no power to *stop itself*. Thus they elude the necessity of providing any *physical* cause for the conservation of motion, and save themselves all that trouble, which they might otherwise have in searching after it. Then, from the principle of a *vacuum*, or space void of all sensible matter, they propose the two following advantages; that a body will have *room* wherein to move, and that being once set a going, there will be nothing in the way to obstruct or diminish the quantity of its motion.

In this manner they account for the continuance of that motion which is rectilinear: but then for the producing of other motion in curves and compounded directions, with which nature is observed very much to abound,

abound, they suppose an emission of immaterial virtues or forces, propagated through their *vacuum* from one parcel of matter to another far distant from it. These virtues are of two sorts: by the one of them, one body is so affected by another as to be *drawn nearer* to it; by the other, it is caused to recede from it: and necessity requires, upon some occasions, that the same parcel of matter be allowed, and that in all its component parts, to have both these powers, though contrary to, and destructive of one another. The names by which they have been distinguished in different ages are εχθρα and φιλια, *love* and *hatred*, *sympathy* and *antipathy*; and now they pass current under the fashionable terms of *attraction* and *repulsion*. But I presume if we were to call them *a pulling* without any hold, and *a pushing without touching*, we should describe all the sense they have, as well as distinguish one from the other. How or when these qualities came into the world, and *what* they really are, this sort of philosophy thinks itself not concerned to declare; but only to affirm that there *are* such; and, if pressed either with difficulties or absurdities, has this to offer in its defence, that the world is over-ruled by

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a supreme intelligence, which can act in *any manner*, and which appears from some observations to act in *this* manner.

These are some of the outlines of the cosmographical system, which was taken up, and cultivated with all the geometrical skill of the great Sir Isaac Newton; who, as an honourable author has truly observed of him, "was made by nature and inclination for mathematical studies*." Most of our celebrated mathematicians, who are led by a natural bent to a like method of reasoning, are confident, that he has transfused into physical subjects the certainty of geometrical demonstration. Hence they tell us, he *has secured his philosophy from the hazard of being disproved;* and have accordingly bespoken all the *discoveries* that shall happen to arise in *future ages*, which, it seems, are to *confirm and enlarge his doctrines, but can never refute them* †. Whether the case does in all points come up to their description of it, we shall be better able to judge, I hope, from the contents of the following sheets.

Other philosophers there are, who believe the

* See the Life of Dr. *John North*, p. 260.

† See *Maclaurin*'s Account of Sir *Isaac Newton*'s Discoveries.

the frame of nature to be a perfect and well-ordered machine: in other words, that the visible system of the world, created, disposed, and set into motion by the finger of God, acts as a machine does; a connection and communication being preserved between all the distant parts of it; for, if you interrupt the contact of a machine, you destroy its motion in all those parts from which the communication is cut off. More particularly they assert, that the fluid æthereal matter of the heavens acts by impulse on the solid matter of the earth; is instrumental in every one of its productions; and necessary to all the stated *phænomena* of nature. Hence they divide the elements into *active* and *passive*; not that they are such by any *inherent* or *essential* difference, but that, according to the order established by the divine architect, they are observed to subsist under these different relations.

This sort of philosophy cannot pretend to be *new*. Certain it is, that all the descriptions and allusions in the *sacred writings* agree to such a scheme of nature rather than to any other. And that the most ancient heathens were in possession of this knowlege, I shall take occasion to shew, before I finish

finish what I have to say upon this subject. When it was in their hands, the *active elements* had a principle of *intelligence* ascribed to them, and were taken for the *Gods that govern the world.* But with those who are taught that the *true God* is distinct from and above the world of matter, though virtually present in it by a providential inspection and superintendence, it will only serve to enlarge their ideas, by setting before them the visible evidence of that divine wisdom, which, with so exquisite a contrivance, and such a simplicity of design, hath adapted physical *causes* to the production of their respective effects: it will introduce them to a knowlege of *things*, instead of leaving them to founder in a set of *hard words*, which, as I shall hereafter shew, have not yet been defined, nor ever can be, so long as the world lasts.

Something like to this was attempted in the last century by Descartes: but his method of deducing the knowlege of physical causes *a priori* was very exceptionable. He was so fond of being thought an original, that although an universal *subtile matter* does certainly exist, he stated the case in such a fashion as to render it suspected; and having assigned a motion to his elements not

agreeing with experience, and such as cannot be made sense of, so long as Kepler's law is admitted, his *hypothesis* was easily brought into disrepute. Many of the learned, however, in other countries, do still endeavour to make the best of it; rather because all experiments shew them the absurdity of a vacuum, and the insufficiency of attraction*, than that they believe the system of their master to be absolutely perfect. And here let me observe by the way, that where nature is the subject of inquiry, no error can be more unfortunate than that of reasoning *a priori*. Men have no right to assume the character of lawgivers to the works of God, but must be content to borrow from them all the laws of their own philosophy; and till they will condescend to do this, there can be nothing but useless wrangling and dispute, even in regard to first principles and fundamentals. Descartes was of opinion, that the world is directed by some subordinate and mechanical causes. In which he seems

* Consult *De Gamaches* Astron. Phys. p. 348, &c. *Regnault*. Entret. Phys. vol. 3. p. 322, &c. *Banieres* Examen. p. 28. & alibi pass. *Le Plusche* Hist. of the Heavens, Book 2. c. 10. As for the *Abbè Nollet*, he refers us for his sentiments to the *Abbè le Plusche*.

seems to have been right only by accident; for as to the kind and quality of these causes, he searched no farther than his own brain; and neglected those undeniable phænomena with which his causes are not to be reconciled.

Sir Isaac Newton, on the other hand, was very diligent in studying those phænomena which belong chiefly to the class of natural *effects*; in the adjusting of which he makes a great figure; but unhappily solves the whole government of the created world by a *nostrum*, which hath never yet been understood; and in the application of which he was not very consistent with himself, as we ſhall find hereafter.

The followers of Newton and Descartes having thus admitted something which is arbitrary in the very foundation of their schemes, we can never expect to see their disputes brought to any iſſue, so long as there are men equally learned and ingenious on both sides to perpetuate them.

While these able philosophers are contending with each other, some in the pursuit of fame, and others in the pursuit of truth, without being able to agree where and with whom it is to be found, I should not dare to inter-

interpose in such a subject, unless I suspected natural philosophy to be a much easier thing than they have made of it; and such as a plain man, who only consults the proper evidence, and pretends to no more wisdom than the rest of mankind, may be able to strike some light upon. This, however, cannot be done in such a manner as to be attended with any good effect, till it is first determined, whether the operations of nature are immediately owing to mechanical causes, or whether they are conducted after a manner unknown to us in empty spaces. Those who affert the latter are supposed to do it with *demonstration* on their side. It would be vain, therefore, to describe the mechanism of the world, and descend to the consideration of any particular effects, so long as even the general method of solving effects by the operation of mechanical agents is thought to be an absurdity. This method of philosophising is the very thing, against which, some of the demonstrations, that have gained most credit with the learned, are directly levelled: and the writings of our modern reasoners, whether metaphysicians or mathematicians, are stored with objections, not only against the reality, but even

even the possibility of a *mechanical agency*. To these their objections I shall now address myself particularly, and endeavour to shew, that not one amongst them all is of any force. As to their *prejudices*, I do not undertake to remove them: but leave it to time, and a farther knowledge of things, to wear off all such impressions as will not bear to be reasoned with.

CHAP. II.

A Reply to the principal Objections in Dr. CLARKE's *Letters to Mr.* LEIBNITZ.

IT will be allowed me, that the celebrated Dr. Samuel Clarke, when he undertook to defend the Newtonian philosophy against Mr. Leibnitz, an able Cartesian, understood what he was disputing about, and hath said the best that was to be said upon the occasion. If this should give but little trouble, we have not much to fear from any body else.

He has brought together several arguments against the doctrine of a general mechanism

mechanism in nature; the first of which, if it can be called an argument, consists in barely afferting the *impossibility* of it. *Certain portions of matter*, says he, *are obliged to follow each others motions by an adhesion of parts, which no* mechanism *can account for**.

Now, that the *parts* of bodies are made to *adhere* together, and some of them very strongly, is an undoubted matter of fact; that *no mechanism can account* for this, or that it cannot be occasioned by the action and pressure of some *mechanical agent*, is what Dr. Clarke ought to have *proved:* instead of which, he takes it for granted; and would put the labouring oar into the hands of his adversaries. For, having mentioned this opinion of Mr. Leibnitz, that the continuation of motion in the heavenly bodies, the formation of planets, &c. are mechanical operations: *whoever*, says he, *entertains this opinion, is*, I *think, obliged* in reason *to be able to explain* particularly, *by what laws* of mechanism *the planets and comets can continue to move in the* orbs *they do through* unresist-

* Collection of papers between Mr. *Leibnitz* and Dr. *Clarke*, p. 363.

ing spaces; *and by what mechanical laws both plants and animals are formed**.

But this is the strangest task that ever was imposed since the labours of Hercules: for we must first allow this author to *empty* the celestial spaces of all matter, and then fall to work to account for the motion of the planets in these spaces by *mechanism*: and we must do it *particularly*, so as to give general satisfaction, without failing in a single article. If these spaces be void of all *resisting* matter, it follows of course that they are also void of all *impelling* matter; for the fluid that cannot resist in some cases, will never be able to impel in others. So that this *reasonable* demand, as he thinks it, is no other than this——we are to explain all things *mechanically*; but then we must take care to do it *without mechanism*. It is not the method of a fair disputant, to require an adversary to disarm himself, and to submit to such a state of the case, as will render it impossible for him to succeed, and prove him to be very weak indeed, if under such circumstances he should ever set about it.

Besides,

* Collection of papers between Mr. *Leibnitz* and Dr. *Clarke*, p. 363.

Besides, there is a great want of perspicuity in Dr. Clarke's way of expressing himself; it being hard to conceive, how the motion of a planet or comet can be continued *by* any *law* of mechanism. *By* some mechanical *cause*, and *according* to some particular *law*, it may perhaps be continued; but his expression supposes, that the law, *after* which any motion is continued, is itself the *cause* of its continuance. The word *law*, in a physical sense, means nothing more than that degree or *proportion*, according to which some cause is observed to produce its proper effect; as that of the effect decreasing as the squares of the distances increase, is the law according to which the cause of gravity is observed to act. And though I may here seem to be criticizing on words, yet whoever examines the affair of *laws, causes, powers, principles,* and *qualities*, as they are set forth by some modern philosophers of great name, will discover no small embarrassment; of which I could give some curious instances. The truth is this: being ignorant of physical *causes*, they have endeavoured to argue such things out of the creation, and have put these *laws* into their place; which has produced a sort of equivocation,

cation, very unintelligible to those who are not apprized of it.

If the questions above mentioned were rightly put, there would be no such great difficulty in replying to them. Thus, if it be required, what mechanical *cause* is present in the celestial spaces, to continue the motions of the planets and comets? our senses tell us, that *light* is diffused throughout these spaces: and we learn from several experiments, particularly from those of *electricity*, that the matter of light can *impel* and *resist*, and that with a degree of power hardly to be believed but by those who are witnesses of it. That the heavenly bodies can move in spaces filled with this matter, and yet feel no *resistance* from it, is not to be demonstrated by any physical proof. I know very well what is commonly urged to the contrary from the *theory of resistances*, of which, in due order, I hope to give a satisfactory account.

If it should also be inquired, after what *law* of mechanism this *cause* will act, the answer is easy; there being but one law known to us, which a fluid, issuing in strait lines from a center to a circumference, can possibly observe; and it is this, that its force will decrease as the angle grows wider; or,

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to speak more strictly, its force will always be inversely as the square of the distance from the center. Dr. Gregory, in his Elements of Astronomy, vol. I. p. 506, has a proposition, wherein he demonstrates that the quantity of *illumination* on the same sphere, placed at *different distances* from the lucid body, is reciprocally as the *squares of the distances*: and this is so well known to every mathematician, that it is needless to insist upon it.

Hence it will follow, that if the rays of light, or any other æthereal matter, whether issuing *from* the sun as from a center, or pressing *toward* the sun as toward a center, have any share in the motion of the earth and planets, the influence of such an agent will be *reciprocally as the squares of the distances*: its power will increase and decrease according to the same law, and for the same reason too, that the quantity of *illumination* does. This law was first discovered by Kepler; and has been greatly advanced by the labours of Sir Isaac Newton. But then I beg the reader to observe, it is a geometrical law; and as geometry is not applicable to immaterial essences, but only to *matter* and *quantity*, it must also be a law of matter,

 that

that is a *mechanical* law; and if the planets are moved according to a *mechanical law*, it must follow, that they are moved *by a mechanical agent*, be that agent what it will. For it would be absurd to the last degree, to believe that the action of an *immaterial power*, or the immediate influence of God himself should be found to *decrease by a geometrical rule*, and its force be capable of being *calculated* at various distances, like the efflux of light from a candle!

Should it likewise be asked, what mechanical *agent* is concerned in the formation, growth, and support of *animals* and *vegetables*? it is very clear, from all experiments, that, in the common course of things, neither a plant nor an animal was ever yet formed or supported under the absence either of *air* or of *heat*; by the latter of which, I would always be understood to mean, the *effect of fire*. An egg has *air** inclosed at one end of it, to be expanded, and made to press upon

* Cavitatis illius, in obtusa ovi parte, utilitates ostendam. *Aërem* intra se continet; ideoque utilis est ad ovi *ventilationem*; ad pulli perspirationem, refrigerium, & respirationem; ac denique ad loquelam. Unde cavitas illa primo *exigua*, mox *major*, ac demum *maxima* conspicitur. *Harvey.* de Gen. Animal. *Exercit.* LXI.

upon the contents by the *heat* of incubation. And what is still more remarkable, air is found necessary, not to the *inside* only, but also to the *outside* of a shell, within which an animal is to be formed; for Mr. Boyle observed, that the eggs of silkworms will not be hatched within an exhausted receiver, though it be exposed to the sun's rays.

With regard to *plants*, every common gardener could have informed Dr. Clarke, that air and fire have an absolute dominion over the whole vegetable kingdom; the expence of stoves, thermometers, and ventilators, might otherwise be spared, and the whole business of gardening transacted in a *vacuum*. But this is so far from being the case, that it is really amazing to see, with what an exactness the several tribes of plants agree in their substance, sizes, and properties, with the *season* and *climate* in which they appear, that is, with the different and unequal distributions of heat and cold all over the face of the earth, of which phænomenon I shall have occasion to take some further notice in a proper place.

As to the body of man, the circulation of the blood, and the spontaneous motion of the limbs, if it can be shewn that any of these motions are carried on without *breath* in the

lungs, and *heat* in the vessels, it will then be time enough to affirm, that they cannot observe a mechanical law, or depend on the actions of a material agent. So far as we are able to judge from what appears to us, the circulation of the blood, and all the animal functions, are sustained and carried on by an internal heat, which keeps the blood fluid, and by the external *air* pressing into the lungs. These serve as a pump to draw the blood from the heart, and the air keeps this pump in motion. Thus the air is to the body, what the weight is to a clock; while the heart, with its valves, performs the office of a *pendulum*, to gauge and regulate the circulation. What I have here said in few words, might be confirmed at large from the observations and experiments of Swammerdam, Bartholine, Dr. Hales, and others. Were the theory of *animal motion* to be stated for us, as that of the planetary motions above mentioned, this author should have set us to account mechanically for the motions of a *living* animal from the example of a *dead* one; the motion of the planets, in *unresisting spaces*, being just as unphilosophical, and as hard to account for, as the circulation of the blood in a dead corpse.

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I may observe, upon the whole, that the way of reasoning Dr. Clarke hath chosen upon this occasion, can do no service to any cause whatsoever. His design is plainly this —to throw some difficulties in the way, and then lay the foundation of his own philosophy in that *ignorance* which is common to us all. For suppose we are not able fully to accomplish the task he has imposed, and give such a mechanical solution as shall be adequate in every instance; must it be allowed, that there is no mechanical agency, till we are able to explain particularly *how* every one of its effects are brought to pass? There may be in nature a thousand examples of a mechanical agency, where the particular *manner* of it hath not yet been discovered, nor the subject perhaps ever examined with such a view. And in some cases, I suppose, the contrivance of an omniscient artist may, after all our labour, be above the reach of human observation; unless the mechanical skill of God and man must necessarily have the same limits.

To build a philosophy on these cases is to begin at the wrong end. The only course that can promise any tolerable success, is to set out with the cases that are well understood;

stood; and thence argue by analogy, to such as are more remote, and difficult of access. But to begin with the things that are unknown is the way to create difficulties where there were none before: and as we shall most probably try to make things of a piece, our ignorance *there* will diffuse itself universally, and give a mixture of darkness to the knowledge we had already obtained.

Dr. Clarke's manner of objecting doth also give me a fair opportunity of turning the tables upon him; and that, as I am inclined to think, very much to the discredit of all his reasoning. For, if it be true, that he who maintains the mechanism of the creation, is *obliged in reason to be able to explain all* effects in that way, and shew how *every thing* is performed mechanically; then it must be equally true, that he who maintains the contrary, and rejects the notion of a general mechanism, is obliged in reason to shew that *nothing* is performed mechanically. For, if it can be shewn that mechanism prevails in any one instance, it will lead us to conclude that it must prevail in every other; upon a bare presumption, that nature has a wise author at the head of it, and is governed by consistent laws, not by such as are capricious and contradictory. The wisdom of

 God

God will be uniform in its operations; and if it works with *natural means* in some cases, and we can be well assured of it, I may venture to say, it does not work without them in any; those only excepted, wherein the established œconomy of the world is interrupted by some immediate act of divine power, or a miraculous interposition. But these are more properly the subjects of divinity, than of natural philosophy, which considers nature *as it is*, and in its regular course; not as it may happen, on some certain occasions, and for sufficient reasons, to be thrown out of its course.

To argue from the absolute *power* of God, exclusive of his *wisdom*, and that he is *able* to act by the unmechanical forces of *attraction*, &c. would but ill become those, whose proper business it is to shew how things *are* done, not how they might be done. Without doubt, it would have been possible with God to have given man the sense of *seeing*, on very different principles from those at present established. The *power* of God wants not the mediation of light, to convey to us a perception of distant objects; but his *wisdom* hath been pleased to make use of this fluid medium, as the natural

instrument

instrument or physical cause of vision. The eye is a complete piece of optical machinery, perfectly analogous to a *camera obscura.*—The *chrystalline humour*, lodged near the protuberant part of it, is a double convex *lens*, or magnifying glass; the *pupil* answers to the hole in the window-shutter; the *Iris* is a moveable curtain, to enlarge or contract the pupil so as to admit a proper quantity of rays; it answers the same end as the *aperture* in a common telescope; and the *retina*, which is an expansion of the optic nerve upon the back part of the eye, is the sheet, upon which the images of the objects are properly coloured in miniature. What occasion for all this *apparatus*, when some quality with an hard name *might* have answered the end as well?

Is not this alone sufficient to convince us, that the wisdom of God hath chosen to act with natural means; that is, with the instrumentality of a fluid medium, and matter properly arranged to receive its impressions? If this is done in *one* part of the body, my reason will be suggesting to me, it is done in *all*; that as the optic nerves are acted upon by a material medium for the purposes of vision, so the *lungs* must play, the

the *heart* beat, the *blood* circulate, and life, sense; and motion, be kept up throughout the whole human frame, on the same plan of *mechanism*.

And if the body of man, which many philosophers have considered as a lesser world, be of a piece with the greater, as the same way of reasoning, if carried forward, will incline us to suppose; the motion of that too is kept up by natural means. The same fluid medium that gives motion to the lungs, or sight to the eye, may conduct a planet in its orbit, and produce all the various appearances that have fallen under the observation of the most industrious naturalist. As there are no vacuums, no attractions, no repulsions in the human frame, but all is carried on by the impression of *material forces*, there is no reason to conclude that these *imaginary* principles (for such I shall prove them to be) prevail in the planetary regions; but rather, that all things are conducted by a like method even there also.

The parallel now before us will serve to detect the weakness of that common argument against a plenum, and a mechanical agency, which is drawn from the doctrine of *resistance*. Some learned men are of opinion,

nion, that if the system of the world were full of matter, a planet must very soon lose its motion. But this argument will make a very indifferent figure when applied to the human body. There, I think, we have a *plenum* undisputed; and the blood, once in motion, is resisted by every artery in the body; the sum total of which resistance, as Borelli * has computed it, is almost incredible. He makes it equal to 180,000lb. Yet this *involuntary* motion continues without any diminution of its velocity, till the machine is quite worn out, or till the providence of God is pleased to put a stop to it by some shorter method.

Can any man think he imposes an unsurmountable difficulty upon God, because he can prove, that the fluids of the human body must meet with a resistance to their motion? Must the frame of man be turned into a *vacuum* upon this account? The fact itself is a sufficient answer to all such pretences. And if the blood is not stopt in its circulation by the resistance of the solids, why should the resistance of a fluid stop the circulation of a planet? for doubtless, if the divine wisdom

* De Mot. Animal. P. II. Prop. LXXIII.

wisdom hath contrived a way to overcome this resistance in one instance, it may in another; and the argument for a vacuum, deduced from the *necessity* for such a thing, will be very weak and inconsequential. But of this, more hereafter.

To induce us wholly to give up the affair of *mechanism*, the author of the papers against Mr. Leibnitz has added the following consideration. "That things (says he) "could not be *at first produced* by *mechanism*, "is expressly allowed: and when this is "once admitted, why after that so great "concern should be shewn *to exclude God's* "*actual government* out of the world &c. "I can no way conceive*."

We have an ambiguity here in the terms, which ought to be removed. For if by *produced* he means *created*, no sober man, I suppose, will dispute that point with him; it being certain, that *creation* was no work of mechanism, but a pure act of the will and omnipotence of the Creator. If by *production* he means that *formation* of terrestrial substances, plants, and animals, which was subsequent to the act of *creation*, it is certain, that in that formation and disposition of

* De Mot. Animal, P. II. Prop. LXIII. p. 365.

of God's works some *material agents* were employed, even the same that operate to this very day. The *natural agency* now in dispute, was the *first* article God thought proper to settle in the disposition of the world: *air*, *light*, and the *firmament of heaven*, were first prepared and put into action: after that the formation of all other things followed in their proper place.

If Dr. Clarke could have shewn, that trees and plants were made to grow before there was any *light* or *air* to be instrumental in the process, he had done something to the purpose: but as far as we can learn, his scheme of philosophy agrees no better with the *origin* of nature, to which he here appeals, than with the present frame and constitution of it.

As for *excluding God's government out of the world*, if that was the design of Mr. Leibnitz, he must answer for it. But it can never follow, that if a *second* cause be interposed, the *first* cause is *for that reason* excluded: no man would be so weak as to affirm that; because every *second* cause, as such, must depend upon the *first*. The author therefore has thought proper to call it an *actual* government; which must mean either

either *immediate* or *real.* If he maintains, that the agency of the divine essence is *immediate* in the production of natural effects, which, in the judgment of some, is the grand *arcanum* of the modern mathematical philosophy, it is incumbent upon him first to prove, that no second cause, created essence, or *material agent* is fitted for the purpose; which, instead of being proved, is hitherto taken for granted. If he means, that the *real* government or providence of God is excluded; neither will it follow, that his government is less *real,* because he rules the world by natural causes, under the direction of himself the supreme cause. If this be a necessary consequence, the scripture itself is chargeable with it; and where it instructs us, that the *sun* is made to *rule over the day,* it must insinuate, that the providence of God does not rule over the world.

When we speak of mechanical causes as doing any thing in the world, Dr. Clarke will immediately take us up, and conclude they are to do it *of themselves**, independent of the divine *power* and *wisdom;* which opinion Mr. Leibnitz, with whom he was disputing, had expressly disclaimed. For my own

* De Mot. Animal. P. II. Prop. LXXIII.

own part, I adhere only to the *matter of fact;* and *that* I know will bear me out against all the metaphysical subtilties in the world. But if the reader should be distressed with any doubts in this matter, only let him remember that matter acts upon matter, not by an *essential* but a *mechanical power*, i. e. by its *motion:* for, in the natural, as in the moral world, we hold that *there is no power but of God.* If this distinction be attended to, all that has been so industriously written in defence of *immaterial impulses* in a *metaphysical* way, by the author of the *Enquiry into the nature of the human soul,* falls to the ground without any particular confutation.

CHAP. III.

An Answer to a physical Objection from Sir Isaac Newton.

I Meet with a third objection, which may be properly termed a physical one, and deserves a particular consideration. "I have explained (says Sir Isaac Newton in the

the *Scholium generale* at the conclusion of his *Principia)* "the phænomena of the heavens "and sea by the force of gravity—which "acts, not proportionably to the *surfaces* of "the particles it acts upon, as mechanical "causes use to do, but in proportion to the "quantity of *solid matter.*" The same thing is somewhat differently expressed by Dr. Clarke, in his notes on Rohault's physics. "There are innumerable phænomena of "nature, and especially that principle of "*gravitation* in all matter, which cannot "possibly arise from the *impulse* of bodies; "for all impulse is in proportion to the "surfaces; but gravity is always answerable "to the quantity of solid matter; therefore "gravity must be attributed to some cause "which can penetrate the inmost substance "of solid matter." P. I. c. 11, & 15.

A person who is tolerably conversant with the writings of Sir Isaac, would naturally apprehend that this assertion of Dr. Clarke is not consistent with them. He has plainly declared, that "what he calls *attraction* "may possibly arise from *impulse.*" Dr. Clarke on the other hand affirms, that the same *attraction* of gravity *cannot arise from impulse,* though Sir Isaac, whose philosophy

he was defending, has granted the possibility of such a thing. There must either be a flat contradiction between them, or some distinction is wanted with regard to the word *impulse*, for the clearing up of this difficulty. The secret then lies here: the *impulse* which Dr. Clarke denies, is *corporeal* impulse, and should arise from the action of some impelling *matter;* whereas that which Sir Isaac Newton allows, is *incorporeal*, if his commentator, Dr. Clarke, who must be supposed to have known his mind, has not misunderstood him; for thus he has expounded the passage—*fieri sane potest ut ea efficiatur impulsu (non utique corporeo*)* "It may be, "that this (attraction) is the effect of *im*-"*pulse*, but this impulse is *not corporeal.*"

The consequence which every intelligent reader will draw from this doctrine of *incorporeal impulses*, gave Mr. Leibnitz and others occasion to charge the *Newtonian hypothesis* with the impiety of making God the *soul of the world*, as the heathens of old did. But this matter is not now before me: our business at present is to consider the force of this objection so far only as it is physical. It is in fact no more than this—mechanical causes

* *Ubi supra.*

causes use to act in proportion to the surfaces; but the cause of gravity acts in proportion to the quantity of solid matter; therefore that cause cannot be mechanical.

Thus much is certain, that every mechanical cause, which is not subtile enough to penetrate the contexture of a solid body, will be stopt at the surface; and the action or force of such a cause will be proportionable to the surface. If there were in nature *no other* mechanical causes but such as act upon the surface, and it could be fairly made out, this objection would be unanswerable. It ought to have been proved, that there really *are* no other; at least it should have been attempted: yet, as far as I can find, it hath not; and I think it never will be, for the two following reasons.

First, because there may be in some cases an impelling matter, which is too subtile for the observation of our bodily senses: and to conclude that there can be no material agency, where it does not discover itself to the organs of the body, is rather too hasty. If the parts of man's body were of the substance of *iron*, and put together in the same manner, he would probably feel the cause of *magnetism*, as plainly as he now perceives

the heat of the sun's rays, or the blowing of the wind against his face: but then it would be of small use to lose the motion of the joints, and receive a polar direction in the body, merely for the satisfaction of feeling that the cause of magnetism is material and mechanical; which perhaps may be discovered, to as much satisfaction, by a more advantageous method.

My second reason for believing that we are to expect no proof of this negative, comes a little closer to the point; and it is this, that the opposite affirmative is evident from a great variety of experiments; there being in nature such mechanical causes as are able to penetrate the solid bulk of bodies, and whose action extends to every single particle of which they are composed. The rays of *light* can pass as easily through the solid substance of glass, if not *more* so, than through the open air: and it is plain, their effect on bodies is not regulated by the exterior surfaces, because an hollow bubble of glass hath the same exterior surface, whether it be empty, or filled with water; yet the light is well known to take a different course through it in these two cases. If a leaf of gold be held up between the eye and the sun's

sun's rays, they are not stopt by the surface of it, as a blast of air would be, but pass its substance with great ease, and appear as a beautiful green colour on the backside of the leaf. The electrical fire, when put in motion, will pass off in a stream through the densest bodies, and can *penetrate the inmost substance of their solid matter*: the influence, therefore, of such a material cause, will neither be confined to the surfaces, nor be proportionable to them: and I am willing to think, that if Sir Isaac had lived to see some wonderful effects of this fluid, discovered for the most part since his death, he would have enlarged his notions very much with regard to the natural power and extent of *mechanism*.

There is hardly a motion in nature which this fluid, when applied by a diligent experimentalist, is not capable of producing. It will give a *rectilinear* motion in all directions; will produce the motions of *rotation* and *revolution*, as a *common fire* will also do. It will keep a body suspended at a certain distance in the air without any visible cause, and make it turn swiftly on its axis. It will accelerate vegetation, increase the motion of the blood in the arteries, raise water into

tides; and, in a word, will shew itself, as a *natural instrument*, to be little less than all-sufficient. Again, *common fire* is a fluid, whose impulse reaches to the solid parts of bodies. A solid ball of iron will conceive a greater quantity of fire, and be longer in parting with it, than an hollow shell of the same diameter. Water is enlarged in its dimensions by the entrance of fire into it; *hot* water being specifically lighter than *cold*; and it is enlarged so equally throughout the whole substance of thc fluid, that it is certain the fire must agitate every one of its solid particles, and, by pressing against them in all directions, remove them farther asunder.

From these and many other experiments, open to common observation, it must appear to every unprejudiced philosopher, that nature is furnished with a mechanical cause, whose activity is not confined to the surfaces of bodies, but extends to their constituent parts, that is, to their *quantity of solid matter*.

The sagacity of Sir Isaac Newton could not well overlook this; and he seems to have apprehended such a thing, having affirmed no more than that mechanical causes *use*

to

to act in proportion to the surfaces; but unless they *always* do so by a necessary and invariable rule, the inference, that gravity *cannot* be the effect of such a cause, is of no force at all. And there is good encouragement to think, that gravity not only *may* be the effect of a material cause, but that it really *is* so; and that this cause might possibly be pointed out, and proved by experiment. But I must remember that I am not now accounting for the difficulties in natural philosophy, but only removing those objections which lie in the way to a *physical* solution of them.

There is a *physico-mathematical* argument of some weight, which ought to be considered before I conclude this chapter. It hath been objected, that *gravity* cannot be owing to any *mechanical* cause, from the manner in which such causes are observed to produce their effect.

Thus, for example, when a ship is put in motion before the wind, the *velocity* of the wind, *with respect to* the ship, will be less when the ship has *acquired some motion*, than when it was at rest; therefore the accelerations in equal moments of time will be unequal. After the first impulse, the acquired velocity

velocity of the body will be subducting more and more from the *relative velocity* of the fluid; on which account, the accelerations in equal times will be less and less, till the resistance the body meets with in its motion becomes a balance to the force that moves it; at which point the accelerations wholly cease, and the ship thenceforward goes on with an equal pace.

This, it must be confessed, is very different from the manner in which the cause of gravity produces its effect: for this cause, whatever it may be, *acts incessantly or continually, and with the same force, upon a body that is already in motion, as upon a body that is at rest; which appears from hence, that it produces equal accelerations in falling bodies in equal times* *.

This property of gravity is manifest from some abstracted mathematical reasoning, which Galilæo confirmed by experiment. If a body should continue to fall during the second moment of time, with the velocity it had acquired at the end of the first moment, it ought to fall *twice* as far in the second moment as it did in the first. But it is observed to fall *thrice* as far: therefore it has derived

* *Maclaurin's* Phil. Discov. p. 241.

derived from its cause in this second moment another *third* quantity of motion, equal to what it derived from it in the first. And this law it will continue to observe in all the succeeding moments, so far as human observation is able to follow it.

According to the received principles, this argument, as here stated, bears very hard upon the mechanism of gravity. What I have to offer against it is this—that the accelerations of a body, moved by wind or water, are continually decreasing *only upon this account*—because the velocity of the body, after the first impulse, approaches *sensibly nearer* to the velocity of the fluid. If the velocity of the fluid should be so great that the velocity of the body shall bear no *sensible proportion* to it, the objection will vanish. And this observation, I humbly apprehend, is applicable to the cause of gravity. For if that effect is owing to any *physical* cause, it will, in all probability, prove to be the same with that which produces such wonderful effects in electricity; the *velocity* of which is not to be measured in any trials we are able to make upon it, and, for ought we know, may be as great as that of the *light* in its progress from the sun and planets: so that

that the velocity of a falling body, as far a experiments have gone, will bear no sensible proportion to it. Therefore the effect ought to be such as it is found to be.

Mr Maclaurin, from whom I have borrowed this objection, mentions it in very few words, and lays no great stress upon it. He thought it improper to *determine* any thing from hence *concerning the cause of gravity* *. And he seems to have judged rightly: for whoever shall hence determine, that its cause is *not mechanical,* will undertake the proof of a very extraordinary *negative;* such as must imply, that he is a complete master of all natural science, acquainted with the utmost extent and power of those mechanical causes, which were contrived and established by a wisdom that comprehendeth all things.

* *Maclaurin's* Phil. Difcov. p. 241.

CHAP.

CHAP. IV.

An Examination of the Argument for a Vacuum, deduced from resistance and the vis inertiæ *of bodies.*

WE are now arrived at that part of the subject, where all the admirers of *demonstration* will expect to see me drop; that is, to the doctrine of a *vacuum*, and the *theory of resistances*, upon which it is founded. The learned gentlemen, who object to the sort of philosophy I am now recommending, know very well, without being reminded of it, that if they have proceeded without evidence in *this* matter, their whole fabric falls to the ground without farther trouble: and if I cannot shew that they have, I am willing to own that all I have yet said, or shall hereafter say, must, in their opinion, go for nothing.

Allowing then that there is a *vacuum* or void space in the world, their argument is very short, and will stand thus:—Bodies are observed to have motion in such a space; but that motion cannot be the effect of any material

material cause, no such cause being present to them.

Should we suppose this to be true, what a confused and heterogeneous mixture of solutions will it necessarily introduce into all our physical discourses? That God does in many cases govern the world by material agents, and conserve the motion of bodies by the activity of secondary causes, is beyond dispute, The support of animal life by *breath*, the motion of a ship before the *wind*, of the sap in vegetables at the approach of the sun's light, of the mercury in a barometer by the *pressure of the air*, of the fluid in a thermometer by the expanding power of *fire*, of bodies impelled and driven off again by the flux and reflux of *electrical æther*, with innumerable other phænomena of nature, all conspire to establish this plain truth. And if it be an axiom in physics, that more causes are not employed where fewer will suffice, how comes it to pass, that those agents which confessedly minister to so many and great effects, are not sufficient for the producing of all? Shall we allow, that God governs the world by a subordinate agency and mechanism in some cases, where that agency appears to us; and deny it in others,

others, merely because we have lost sight of it, or because it would make against us? A philosophy that labours under this difficulty, and is one while working with a *material* cause, and in the next breath with an *immaterial* one, be it ever so ingeniously put together, will after all be liable to this grand exception, that at best it is *inconsistent*, and unworthy of God. Every body must see and know, that there are material causes acting in the world; and he that denies it, must deny his senses. If these causes are not sufficient to perform *all* the stated operations of nature, then the Creator hath made use of such means as are not proportionable to the end. If the Creator himself performs them by the immediate agency of his own substance, then is there no need of any *other* causes; they are all *superfluous*. But that there are other causes is abundantly evident; therefore they must be capable of answering their end, and every material effect will be immediately owing to a material cause. What I here say is grounded on this reasonable *postulatum*, if it may not rather be called an *axiom*, that the wisdom of God is *consistent with itself* in its operations, and that he wants neither power nor skill to avoid

avoid the error of inconsistency: grant but this, and the argument amounts to a *demonstration.* I must confess, it appears to me to be so unanswerable, that if I could not take off the pretended evidence for a *vacuum*, I should nevertheless be satisfied that it was a sophism, and impute its whole force to a want of skill in myself to lay open and detect the fallacy of it. And now let us proceed to give it a particular consideration.

I have a manuscript-paper by me from a learned and ingenious gentleman of Cambridge, wherein the argument for a *vacuum* is stated very closely; and he will not be offended with me, if I take the liberty of setting it down in his own words; for I know how to honour a man of parts and diligence, though we may happen to differ in some of our sentiments.

" You will hardly (says he) deny the *vis* " *inertiæ* of matter, which Sir Isaac Newton, " and every author, but the *materialists* " think demonstrably essential thereto, and " proportionable to its quantity; and there- " fore, that it must hold equally in the most " *subtile æther*, as in the grossest matter. " Hence it follows, from the *different degrees* " *of resistance* to bodies moving in different

" mediums,

" mediums, that equal portions of different " mediums contain different degrees of *vis* " *inertiæ*, and consequently different *quan*-" *tities of matter*. But how can different " quantities of matter be contained in equal " bulks, without supposing *vacuities*, at least " in one of them? No *subtile æther*, per-" vading the pores of the grosser medium, " will solve the difficulty; because such an " æther must itself be *more porous* than the " grosser medium, else through its *vis in*-" *ertiæ* it would cause an *equal degree of re*-" *sistance*, contrary to fact and experience. " Now what can this porosity of the æther be, " but *interstitial vacuities*? Must we invent " another æther to pervade the pores of the " former, then another, and so on, till all " the pores be filled? But this only drives " us again upon the difficulty we have been " endeavouring to shun; namely, that all " bodies are *equally dense*, and ought *equally* " *to resist the motion* of other bodies through " them. This, allowing the *vis inertiæ* of " matter to be essentially proportionable to " its quantity, is a *strict demonstration* of an " interstitial *vacuum*: and therefore diffi-" culties started against it, though we could " not solve them, ought not to move us."

 We

We are now possessed of the objection in its full force. All matter, from its *vis inertiæ*, or a natural indisposition to change its place, must give a resistance to motion in proportion to its quantity: and as we find a different degree of resistance to bodies moving in different mediums, there must be different quantities of matter in equal spaces; and consequently there is just so much *more* of vacuum, or absence of matter, in one of the spaces, as there is *less* of resistance: where there is *no resistance*, there will be *no matter*: so that we must either correct the modern doctrine of the *vis inertiæ*, or allow this to be, what Sir Isaac himself hath called it—*demonstratio vacui*. As the *vis inertiæ* is a principle of so much consequence, I am obliged to enter upon an experimental enquiry into the nature of it; in the progress of which, I think it will appear that such an enquiry was never made by Sir Isaac himself, nor by this ingenious gentleman; who will find he has taken up with a principle, which he never gave himself the trouble to examine. For, after all that can be said, *experiment* must be the test; and to that I shall appeal for the truth of what I am going to offer.

We find then, that if a body be at rest, a certain

certain force is required to remove it out of its place; and this force is supposed to be necessary only on account of a *vis inertiæ* in the body: for which reason, the force required must increase, as *the quantity of matter* increases in the body to be removed. All this will be true, if the *vis inertiæ* is true: but it is contrary to fact. Let us suppose this body to be of a pound weight, and suspended by a line, so that on occasion it may vibrate as a pendulum. If you would move this body in a direction *upward*, the force required must be superior to a pound; if sideway, in the segment of a circle, of which the point of suspension is the center, a much less force will do the business; and this force being the true index of the *vis inertiæ*, if that be found to alter, though the *quantity of matter* be ſtill the *same*, it proves that the *vis inertiæ* is a changeable thing, depending on some certain circumstances, which must be taken into the account. And it will appear, that if you can calculate the force which the action of gravity will have upon the body, when elevated to any angle, you will then know what force is requisite to overcome its *vis inertiæ* or indisposition to motion.

If the same body be taken in the hand and left *at rest* in the air, no force at all is required to put it in motion *downward*: for the cause of gravity immediately sets it a going in its proper direction. So that, *cæteris paribus*, the *vis inertiæ* in all bodies, being more or less, just as you concur with or contradict the action of gravity upon them, seems *in fact* to be no other than a consequence of their gravity.

When we attempt to give a motion to a body different from that of gravity, we find it already pre-engaged by a determination towards the earth's center: and this natural force is making its effort every moment against any foreign force that can be applied to it; to which it is owing, that projectiles, instead of proceeding in a straight line, describe a parabolic curve. If gravity and the *vis inertiæ* were things essentially different, and independent of one another, *each of them* must occasion a resistance proportionable to the quantity of matter; and the *whole* resistance, as discoverable by experiment, would be the *sum* of two different resistances, the one proceeding from the cause of gravity, the other from the *vis inertiæ*. But I am fully persuaded, that in all entire or detached bodies,

bodies, we shall discover no resistance to a change of place, but just so much as ought to proceed from the action of gravity upon them, and no more.

If this be true, if the *vis inertiæ* be only the consequence of another principle, two corollaries will arise, sufficient to dispatch all the argumentative part of the above demonstration. For then it will follow, that if we can alter the state of a body in respect of its gravity, or its natural tendency *downward*, we shall, at the same time, alter its state in respect to its *vis inertiæ*, or natural indisposition to move when left at rest: the truth of which will appear from an easy experiment.

Take a light glass bubble, and load it inwardly with mercury, or any other heavy substance, till it is precisely of the same specific gravity with water. This done, we will suppose it to weigh two ounces. Let it now be suspended by an hair to the arm of a balance, and laid at rest upon a table: if you would raise it from thence, and give it a motion upward, you must charge the other end with a weight some small matter above two ounces; which may stand for the force requisite to overcome its *vis inertiæ*. Let

the body then be placed near the bottom of a vessel filled with water; in which position it will remain at rest: but if you would now give it motion in the same direction as before, it may be done with a single grain, that is, with only one thousandth part of the force required in the former case. The reason of this seeming paradox is this; the motion given does really coincide with that of gravity, though in appearance it contradicts it. For the body being of equal weight with an equal bulk of water, when the body has moved out of the space it occupied at rest, an equal bulk of water, through the action of gravity upon it, has descended into that space; and if we put 1000 for the force necessary to raise the body, and 1000 for the force of the subsiding water, the difference between these two leaves a remainder for the *vis inertiæ* = 0. Some quantity, however indefinitely small, must be allowed to produce an *inequality* between the body and the water; for where all things are equal, no motion can ensue. But how much the *vis inertiæ* has to do in this experiment, I leave to be determined by better judges, when they have considered it. It may like-

wise

wise be added, that after the bubble has been moved by a force equal only to a *single grain* through a space of water equal to itself, *twice as much matter has been put in motion* thereby, as would have been moved in a vacuum by a force somewhat superior to *two ounces*, because the bubble has displaced a quantity of water equal in weight to itself; and water *resists* a moving body nearly a thousand times more than air. But how can all this be possible, if an *indisposition to motion be essentially proportionable to the quantity of matter?*

My second corollary applies itself directly to the demonstration. As the *vis inertiæ* is a necessary consequence of gravity, if there be any fluid, be it what it will, which acts as the *cause* of gravity, that fluid must itself be void of gravity, *considered as an effect*, and consequently of that resistance which has been ascribed to the *vis inertiæ*. To say, then, that the *vis inertiæ must hold equally in the most subtile æther as in the grossest matter*, and that, from the different degrees of weight or resistance, *different quantities of matter are contained in equal spaces*, is to beg the question, that gravity has no material cause. But it would be unfair to demonstrate that it has none, merely by attributing to it such a

property; as from its nature and office it cannot possibly have.

It is incumbent, therefore, on all those who would build a philosophy on the *vis inertiæ*, first to shew us what it is, and to prove by some experiment, that there really is such an *original* principle in matter, to be discovered *apart*, and *independent* of every other principle at present established in nature, before they can raise from it one single conjecture, much less a demonstration. I say, of *every* other principle; for a resistance to motion may be occasioned by more principles than one. A mass of iron or stone, first examined with respect to the principle of *gravity*, then to that of *cohesion*, or the application of its constituent parts to one another, will teach us, that the *whole* quantity may be put in motion with respect to the earth's center, much more easily than *half* the quantity can be moved with respect to the other half: so that if the force with which some solid bodies cohere, were to take place in matter, as universally as gravity now does; we might compute the *vis inertiæ* to be ten thousand times as great as it is, because we should oppose the cohesion of bodies, where we now oppose their gravity.

Were

Were all matter at rest, and the action of the elements made to cease, so that not a single particle of matter should have any determination to one sort of motion rather than to another, that would be the time to make an experiment on the *vis inertiæ*. But this principle, so far as it is subjected to examination under the present economy of the world, is a thing unfixed and consequential, not uniform and independent, as the mathematicians have supposed; whose greatest misfortune it hath been, not to consider things *as they are*, but to feign an arbitrary and abstracted state of matter, and thence to argue upon it in its dependent state; when they are really more different, than the ore of a metal deposited in the earth, from the same metal formed into the wheels of a clock. And what is much more offensive, the same philosophy which has given to matter an *indifference* to motion by the *vis inertiæ*, has also given it an *inclination* to motion by the virtue of *attraction*; both of them *inherent* (as shall be hereafter shewn) in the same particles. The former of these does indeed seem opposite to *materialism*; but the latter has so strong a relish of it, that a friend to the principles of Spinoza

hath blended them both together *. And even Dr. Derham, an undisguised and well-designing author, has granted as much as Epicurus himself would have required of him. It was his opinion, that, in *the first production of matter*, the great Author *of all things INSPIRITED the* materials *of which the world consists, with such an* active quality, *as serves to preserve the globes entire, and enables them to revolve about their centres* †. If this passage does not allow to matter a power of directing itself, and conserving its own motions, I know not what to make of it. But it is no concern of mine, so I return to the argument; leaving it to those who pretend to have renounced *materialism*, to reconcile their own conjunct doctrines of *inert matter*, and *inspirited materials!*

* See the *Physical* paragraphs in a piece intitled an *Essay on Spirit.*

† Astro-theol. p. 148.

CHAP.

CHAP. V.

The argument from resistance proved to be an absurdity; as it implies, that the cause of motion must resist the motion which it causes. A plain experiment to illustrate and confirm the author's reasoning.

THUS much, I think, may suffice to shew, that the celebrated demonstration of a *vacuum* has *set out* wrong. It will be as easy to prove, even waving all that has been said on the *vis inertiæ*, that it has *concluded* wrong; if the *relation between a moving body and a resisting medium* be rightly underſtood.

When a pendulum is made to swing in *air*, *water*, or *mercury*, the resistance it meets with is greater, as the medium is denser; and as a plenum of æther, such as the mechanical philosophy requires, would be more dense than any other fluid, its resistance, they say, must be greater: no motion could possibly continue in it. But then as motion is observed to continue in the heavens, without any *sensible diminution*, there

there can be no resistance in the heavenly spaces, and consequently no matter of sufficient density to occasion it.

This was Sir Isaac Newton's way of computing resistances, and the use he made of them when computed. That we may see whether this doctrine agrees with experience, let us suppose a ship, with its sails spread, to be in motion before the wind: every body must allow me, that if the wind were to keep its direction, and the ship to have an open sea, it would go quite round the globe; and for the same reason that it makes one revolution, it would make another, and so on *ad infinitum*. Are we to say, that the *air*, in which it moves, is an *unresisting medium?* We ought to say this, if the demonstration above mentioned really is what it pretends to be. But the truth is, a medium may, *in its nature*, be a resisting one, and yet *in fact* give no such resistance as shall be any impediment to a body moving in it. For let any person tell me, how much resistance the ship receives from the air in this case? The answer must be—less than none: the resistance here is a negative quantity; and the ship is so far from losing its motion, that it is continually *receiving* it,

as

as it passes through the air; yet it would be false to affirm of air in general, that it is not a resisting medium. As to the *water* the ship sails upon, this being not the *cause* of its motion, will serve to retard it; but as the continued impulse of the air behind is superior to the sum of all the following resistances, 1st, of the *air before*, 2dly, of the *water* the ship sails upon, and 3dly, of the *cause of gravity* which is continually acting upon it; the motion will continue notwithstanding these impediments.

Were it to be laid down as a general rule from this particular instance, that *water* resists motion, but *air* does not; neither will this coincide with experience. A cork, or any other light body, thrown upon the stream of a sluice or floodgate, will be carried off with it; and as it is common for a considerable part of the water to return again upon the stream in a curve, if it be obstructed by the banks, and have but a narrow outlet, the cork may come about with it, and complete its revolutions, so long as the cause continues to act upon it. The water gives no more resistance in this case, than the air did in the other: and thus

it will happen universally, that every fluid, where it is the *cause of motion*, will not be found in that case to give any *resistance*, be its quantity of matter great or small.

We are now prepared to return to the pendulum. If it vibrates in *air*, the air will retard its motion; and there is a good reason why it should do so, for air is not the *cause* of its motion. If in *water*, neither is that the cause of its motion; and it will give a greater resistance to it in proportion to its quantity of matter, that is, in proportion to the action of gravity upon it. If in *quicksilver*, it will meet with a still greater resistance, for the same reasons. But if there be any elementary æther, acting as the natural *cause of gravity* in bodies; it is just as absurd, to search for the resistance of *such a fluid*, from the motion of a *falling body;* as for that of the *air*, from the motion of a ship that sails by it; or for that of water, from the motion of bodies carried down by a current of it. If one philosopher may conclude, that gravity cannot be owing to any material fluid, because he has found that this fluid does not *resist* a *gravitating body;* may not another demonstrate, with equal truth,

truth, that a ship cannot sail by the action of the air upon it, because he finds, from the nicest observations, that the air does not *deprive* it of its motion?

Lest the reader should have suspected me of a design to prejudice him beforehand, and to inject scruples through a want of better arguments; I did not observe, at the beginning of this disquisition, that Sir Isaac had drawn two opposite conclusions from a capital experiment relating to the affair now before us, but it will be proper just to mention it in this place. Having caused an empty wooden box to vibrate as a pendulum, he loaded the same box with 77 times its own weight of metal; and in this latter case found the motion to be retarded more than it ought to have been by the theory. In two different editions of his Philosophy, he imputes this to two different causes, without the least hint or apology to his readers for such an important change in his opinion. In that of 1687 he accounts for this, from an increase in the *resistance of the air*, occasioned by a swifter motion in the heavier pendulum: and has demonstrated elsewhere, that the resistance of a fluid to a body moving in it, must increase

in a *duplicate ratio** of the body's velocity; but this consideration hath no place here. In that of 1726, he imputes this same effect, without any repetition of the experiment, to the resistance of a *subtile medium* against the solid parts of the inclosed metal; and mentions not a word about the *resistance of the air*. But herein, it seems, he corrected his philosophy not for the better, it being absurd, that the resistance of a *subtile æther* should be discovered in such a case as this.

This great man seems to have laid it down as the foundation of these conjectures, (for I hope they are not both *demonstrations*,) that an experiment, which requires machinery, can be performed absolutely without friction; the contrary to which is well known to every mechanic. It is reasonable to think, therefore, that the friction between the hook and ring, on which his pendulum swung, must have been somewhat increased

* The refiftance a body meets with from a medium, is as the velocity of the body, and the fpace of the medium paffed through by it, multiplied into each other. But that fpace will always be as the velocity; therefore the refiftance is, as the velocity multiplied into itfelf, that is, as the *fquare of the velocity*.

increased, when the ball was loaded with a weight 77 times greater; and the difference he found, was no greater than might arise from such an impediment, though the instrument were ever so perfect. It is hard to say, how a man of genius, as he certainly was, could throw a plain experiment into two such different shapes, neither of which are agreeable to reason. Perhaps he thought it would suit better with the principles he was endeavouring to establish, not altogether to deny the existence of a subtile æther, as he did at first, for that would have been too much; but rather to ensure his philosophy, and keep this æther from breaking in upon his system, by imputing to it a degree of *resistance*. Whether the learned will consider of these things, I cannot pretend to judge; in time perhaps they may: but, for a while, I presume, he that ventures to interpose, must be content to let the reproach fall upon himself. There was a time when men had given up their understandings to the logic of the schools* and the quirks of Aristotle;

* I will give a ſpecimen of their *manner*, pertinent to the ſubject we are upon. It is a *logical demonſtration* of a

Aristotle; and woe was to the man who dared to publish a suspicion against them.

That

vacuum, extracted from *Lib.* 4. c. 6. of *Ariſtotle*'s Phyſics. Ου γαρ αν δοκοιη ειναι κινησις, ει μη ᾗ κενον· το γαρ πληρες αδυνατον ειναι δεξασθαι· ει δε δεξαιτο· και εστι δυω εν τῳ αυτω, &c. *If there be no* vacuum, *there can be no* locomotion. *For a ſpace already full cannot receive any thing into it; if it did, there would be two bodies in the ſame place*; *which is an abſurdity.* Some of his Commentators put it thus—Probatur aſſumptio: quia corpus quod locum mutat, vel inani ſpatio excipitur, vel pleno; ſi inani, habetur propoſitum; ſi pleno, ſequitur duo corpora ſeſe permeare ——"*The aſſumption is thus proved: becauſe a body that changes its place, is received either into a ſpace* full *of matter, or into one that is* empty: *if into an empty ſpace, the point is proved*; *if into a full ſpace, then it follows that two bodies muſt penetrate one another's dimenſions.*" And *Ariſtotle* tells us of one *Meliſſus*, an ancient ſophiſt, who being reduced to the laſt extremity by the force of this miſerable argument, and determined not to admit a *vacuum*, denied the reality of motion, and held the univerſe to be immoveable. Had this philoſopher truſted to experiments inſtead of logic, he might have ſilenced his adverſaries with very little trouble. For if a bullet be put into a bottle quite full of water, and cloſe ſtopt down, we have a ſpace filled with an *incompreſſible fluid*, which conſtitutes as good a plenum as need be deſired; yet, upon inverting the bottle, we find the bullet can move from the top to the bottom, or from one ſide to the other, as freely as if the bottle were empty. Does it move into an empty ſpace, or into a full one? why, truly, into neither; for the bullet and the fluid *change places* with one another, ſo that the motion is not hindered, though the ſpace is always full of matter.

That fashion is now exploded, and we are all enslaved to the pretences of a *mathematic* certainty. But if the doctrine of a vacuum is really weak and without foundation, this fashion will have its period like the former, and we shall be restored again to the enjoyment of our philosophical rights and liberties.

It appears, then, that the *vis inertiæ* of matter, under the present constitution of natural things, is no fit principle for a philosopher to begin with; and that even supposing such a principle, I say supposing such a principle, yet to argue from that to *physical causes* is an absurdity: for when any fluid matter becomes a *cause of motion*, the case is quite altered; and its *resistance*, be it ever so great in *other cases*, will be of no account in *this*. The gentlemen who have reasoned from this principle, have never once attempted to inquire what will be the case, where matter *gives motion* to other matter; but, taking it for granted that the great author of nature has created a set of elements, for no single purpose, but to obstruct bodies in motion, have drawn themselves into the palpable absurdity of proving, by a mathematical demonstration, that a matter of fact is an impossibility. Of which, if any

doubt should yet remain, I will subjoin the following experiment, with a few short reflections upon it.

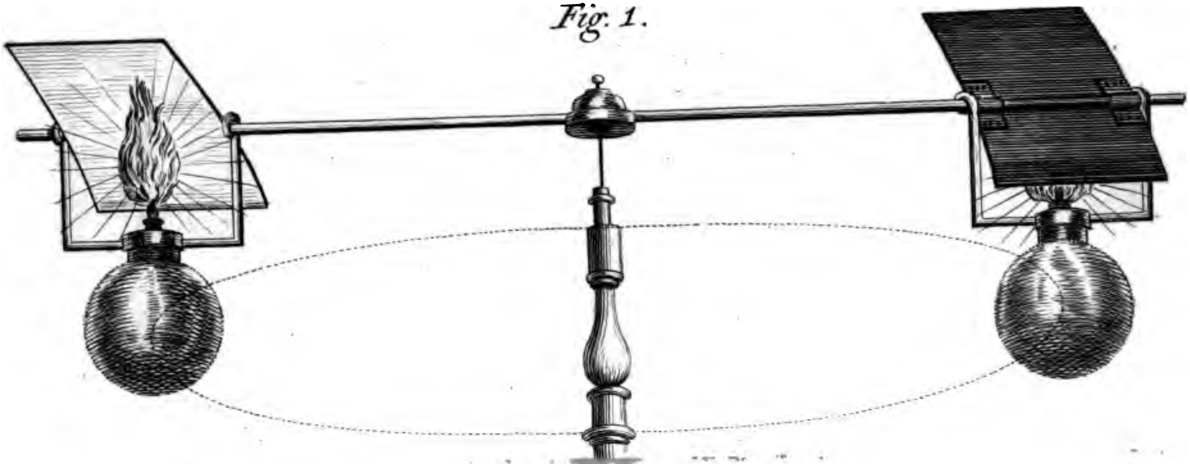
At the extremities of a steel rod of two feet in length, let two lamps of thin glass of a spherical figure (or any other that the operator chooses) be suspended as in the figure, (see plate 1. fig. 1). Over these lamps let there be two vanes of plate-brass placed with contrary aspects, and inclined to about half a right angle. The rod thus furnished is to be poised by means of a cap fixed to the middle of it, on the point of a needle, supported by a foot and pillar. As soon as the lamps are lighted, the machine will begin to turn upon its centre, making several revolutions in a minute, and will continue thus to move so long as the lights continue burning: and supposing the lights to have a perpetual supply, the consequence of that would be a *perpetual motion* in the machine.

We will imagine a mathematical philosopher to be contemplating this sight at a distance. If his eye is in the plane of the motion, the lights will appear to move backward and forward in a straight line: but as their velocity will be apparently unequal in different parts of the line, he wil

conclud

PLATE I. to face P. 68, Vol. 8.

Fig. 1.



conclude they move in a curve; and by considering attentively in what proportion the apparent motion is accelerated and retarded, he will discover that curve to be a perfect circle. Thus far he argues as an *astronomer* and *geometrician*: therefore his conclusion will be undeniable; and I mention this to shew the distinction between *astronomy* and *physics*. But, in the next place, he proceeds to investigate the *causes* of this motion: and having found, as he imagines, that all matter must *resist* motion in proportion to its quantity; if the lights circulate in a *resisting medium*, the velocity he concludes must be diminished, and by degrees be utterly lost. But having observed for several days, and he might do it for as many hundred years, that they continue to move with the same velocity, and complete their periods exactly in the same time, as when he first began to make his observations; he concludes, they must move in an *unresisting space**: and having dispatched all *material* impulses

* "Againſt filling the heavens with fluid mediums, unleſs they be exceeding rare, a great objection ariſes from the regular and very laſting motions of the planets and comets—thence it is manifeſt, that the heavens are void of all ſenſible reſiſtance, and by conſequence of all ſenſible matter." *Opt.* Q. 28.

impulses out of the way, assigns a *projectile* force as the cause of their *progressive* motion, and an *attractive* force, exactly counterbalanced to it, (that is, equal to the *versed sine* of an arc described in a given time,) as the cause of their *circular* motion: affirming, at the same time, that these two forces are sufficient to account for all the phænomena, and will do it *better than any material medium whatsoever* *; and that in the whole course of this reasoning, he has not *made one supposition* †. The sum of this evidence is given us in a few words by that skilful mathematician Mr. Cotes, in his preface to the *Principia: Corpora progrediendo motum suum fluido ambienti communicant; communicando amittunt; amittendo retardantur.*—"Bodies "in their progression *communicate* their mo-"tion to the surrounding fluid; what they "communicate they *lose*; and by losing it "they are *retarded.*" Then he undertakes to prove, that motion cannot be kept up by the impulse of any fluid whatsoever, but upon the following condition—*nisi velocitas absoluta*

* "The motion of the planets and comets being *better* "explained without it." *Newt.* Opt. Qu. 28.

† "Hypotheses non fingo." *Princip. ad fin.*

soluta fluidi recurrentis duplo major fuerit quam velocitas absoluta fluidi propulsi; quod fieri nequit—that is, "unless the absolute "velocity of the fluid which falls in *behind*, "be twice as great as the absolute velocity "of the fluid driven away *before*; which "cannot possibly be *." We have in these words the whole strength of the Newtonian *hypothesis;* this is its fundamental argument: yet if it be compared with the present experiment, there is not one word in it, from the beginning to the end, that will hold true. For, in the first place, these two bodies cannot, in Mr. Cotes's sense, *communicate their motion* to the surrounding fluid, because they were left *at rest*, and had *none to communicate.* They are no *projectiles*: and the mathematical philosophy having made *projection* its first principle of motion, is entirely to seek, where *that* is out of the question. Secondly, as they communicated no motion, they *lose* none; but are continually receiving a fresh and equable supply of it: for which reason, thirdly, they are not *retarded;* but are possessed of a

motion,

* This, by the way, will prove, that when a cork swims down a stream, the water *must* run twice as fast *behind* as it does *before* it.

motion, which, in theory, is absolutely a *perpetual* one. Whence it appears, fourthly, that the *fieri nequit*, to which Mr. Cotes hath reduced himself, hath affirmed too much, and confuted itself. For if the *pressure* of the surrounding fluid be greater on the illuminated side of the vanes, than its resistance on the opposite sides; that *inequality of pressure* will necessarily produce a motion toward the weaker side; and for the same reason that it produces, it would also conserve the motion for ever. Fifthly and lastly, the well-known inference from a *continuance of motion* is worst of all: for, if the machine were placed in a *vacuum*, that is, in a space void of *air*, the lights would expire, and *motion* be at an end. A small hint will be sufficient here by way of application; only let it be remembered, that the lights we use for experiment-sake, will decay in spite of us; whereas that lamp, which God hath lighted up in the world, never goes out. And he that can retain so mean an opinion of the *sun*, that *marvellous instrument* of the divine wisdom, as to suppose it acts, not by the emanation of its *light*, but by its *quantity of solid matter*, should *put out* the two lamps and *weigh* them, in order to ac-

6 count

count for this experiment. If this is not enough to convince the ingenious part of our mathematicians, that their science hath been misapplied, and that their way of reasoning upon *physical causes* is fundamentally wrong, they must be left to philosophize *suo more:* if they are deaf to the evidence of *nature*, it is hardly to be expected they will yield to any remonstrances of mine.

As the doctrine of a *vacuum*, and the *theory of resistances*, are points of so much importance, I have tried to be as particular as the cause required, and as methodical and perspicuous as my small abilities would allow me. If there be a considerable defect in any of my deductions, I shall be very glad to be better informed; and perhaps some of the followers of Sir Isaac Newton may shew so much candour and humility toward a man who *means well*, as not to think him too insignificant to be taken notice of.

CHAP. VI.

A Geometrical Argument for a Vacuum examined and refuted.

EXPERIMENT and logic having both failed in the demonstration of a vacuum; let us see what stress is to be laid on *geometry* in the case before us: for we have been so stunned of late years with its praises, that it will be neither prudent nor handsome to overlook its pretensions. Dr. Keil, the astronomical professor, was a very eminent geometrician, and as strenuous an advocate in behalf of a vacuum. To convince us that there really is such a thing in nature, he offers the following demonstration, which I fix upon, because it has the author's own commendation, who calls it an *invincible* one, as the reader will find in the 17th page of his *Philosophical Lectures*. He desires us to "suppose all the matter in the universe to "be amassed into two spheres, which may "be represented by two circles, whose "centers are A and B. If these spheres "touch one another, it is necessary that "they

"they touch one another in one point only "by the elements of geometry—and there-"fore there will be betwixt the other points "of these spheres a certain and determinate "space not replete with matter." Hence the author concludes "that there is *in* "*reality* a space distinct from all body. p. 19.

This is Dr. Keil's *invincible* demonstration: for the erecting of which, you are only to allow this small supposition, that the omnipotence of God might possibly accumulate all the matter of the universe into two solid spheres; and because there *would be* in this case a space void of all matter, it follows, in his way of reasoning, that there *really* is such a space. This author seems to have been so full of geometry, that there was no room for any logic; else he might have picked up enough of it at Oxford to have taught him—*a posse ad esse non valet consequentia.* Besides, it is the proper business of a philosopher to consider the operations of nature, as nature is now constructed; where, I apprehend, he will find work enough without making a new world, or shuffling the old one into a new shape. But Dr. Keil imagined it would edify us

more,

more, to tell us what strange things would happen, if the world were all taken to pieces, and put together again in such a form as could answer no one purpose of the creation.

If a question had been put to him, whether the motion of a *pendulum* in a clock is preserved by the action of occult virtues, propagated through void spaces from one wheel to another, or by a contact and bearing of the parts upon one another from the weight to the pendulum; he might have demonstrated the former *invincibly*, by supposing, that if the matter of the whole machine were melted down, and made up again into a couple of wheels, their circumferences could touch one another but in a single point; and a man might make a clock upon this principle, with just as much accuracy as he can philosophize upon the other. He that will impartially consider this, and many other geometrical arguments of the same complexion, (with which I could fill a book if it were necessary,) will not be very hasty to believe any proposition, because it is *said* to be supported by mathematical evidence; which, though it be strong in its proper place, and undeniable if considered in the abstract, is nevertheless, when misapplied,

just

just as weak as any other sort of evidence that is equally impertinent. The lovers of mathematical learning, like other men, are too fond of magnifying their favourite science; and will be introducing it, where it can add no light, but will spread an air of mystery and darkness over a subject, in itself plain and intelligible enough. Such unseasonable applications of it are so far from advancing its credit with sober men, that they are in danger of bringing a pleasant and profitable branch of learning into contempt.

It was an observation of the excellent Lord Bacon, whose judgment in these matters hath never yet been called in question, —*optime cedit inquisitio naturalis, quando physicum terminatur in mathematico**, "Every "natural disquisition is brought to its pro-"per issue, when a physical principle ter-"minates in a mathematical operation." The reverse of this is the practice of Dr. Keil: he perceives that a thing will hold true in the *mathematics,* and then turns the world upside down to make his *physics* agree with it. If that be the best philosophy, which goes from physics to the mathematics; that

* Nov. Org. L. II.

that must needs be the worst, which goes headlong to the mathematics before it is ready for them, and canonizes a blunder by a demonstration. So that Dr. Keil was rather too severe in censuring so unmercifully, and laying such an heap of hard names upon his adversaries, "whose errors," he says, "spring from hence, that men ig-"norant of geometry will presume to philo-"sophize, and give the causes of natural "things." For, be it ever so true that some philosophers have not been geometricians, he hath shewn it to be equally true that every geometrician is not a philosopher.

I do not say this to discourage the study of the mathematics: and if I had such a design, my influence is too small to be attended with any bad consequences. However, I am far from designing any such thing; but, on the contrary, am glad I know the value of mathematical learning, and would recommend the practical part of it to the study of every person who does not want leisure, has no natural indisposition for it, and is willing to make a progress in natural philosophy; which, so far as it hath motion and quantity for its objects, cannot be rightly understood without a moderate degree

of

of skill in the mathematics. If this study should become more fashionable among those who are already learned in other respects, it might deliver us from the bondage of some tyrannical prejudices, which at present do very much obstruct the advancement of natural knowledge. Electricity, which has given to this age an advantage over all that went before it, and should have opened to us a new world of philosophy, has left us just where it found us; and the curiosity of the public with regard to that article hath nearly subsided, while the treasures of nature are still locked up under the magic of *attraction* and a *vacuum*. And here we are like to remain; unless the efforts of some future philosopher, more skilful and fortunate than I am like to be, shall rouse the learned from their lethargic admiration of a few hard words, dressed up with geometrical lines and *algebra*.

All I wish for therefore is this, that our young gentlemen, (for as to those who are far advanced in age and opinion, though I reverence their characters, and am glad to take the benefit of their labours, it is too late to drive them upon any fresh inquiry,) that

that our young gentlemen, I say, whose minds are disengaged from systematical views, would avoid all implicit obedience to names and characters, so far as they can do it without any offence to good manners, and bend their attention to such experiments as relate to a *material agency* in nature; which kind of experiments have neither been sought after, nor examined into, as they ought to have been: and would likewise add to their other learning, a competent degree of skill in practical geometry and arithmetic. For it is the misfortune of these times in particular, that those who are ignorant of the mathematics, are apt to think they have nothing to depend upon in physics, but the *authority* of the eminent geometricians; whose reports, however sanguine, premature, and accommodated to their own fancies, they are obliged to receive just as they happen to be delivered: and while they are not aware how much may really be done by the mathematics, and what great assistance they will give in the proper place, are drawn in to allow them much more than their share. On the other hand, a mathematical scholar, whose judgment hath not been

infected,

infected, doth know very well, that geometry can as soon *create* a system of politics, as a system of physics. He knows, that in every physical operation, he must have *physical data* to begin with; and that if he is wrong *there*, all the geometrical skill upon earth will never set him right; but rather lead himself and others into the danger of perpetuating the mistake, by calling the work a *demonstration*.

END OF THE FIRST BOOK.

BOOK II.

Attraction and Gravity considered at large.

CHAP. I.

Attraction *inquired into, from the writings of* Sir Isaac Newton, *and the most eminent of his followers.*

IN the former part of this Treatise, I have made it appear, that the only rational and intelligible philosophy is that which attributes all motion to the action of matter upon matter; or, which is the same thing, that maintains an agency of material and secondary causes, under the direction of God, the moral governor of the world, and the supreme cause of all things.

To such a philosophy as this, I have attempted to clear the way, by removing all the principal objections of our modern learned

men: and if the supposed evidence for a vacuum, depending upon the famous theory of resistances, which gained so much credit with Mr. Cotes, and many others, as to be unhappily mistaken for a *demonstration;* if this, I say, has been obviated to the satisfaction of the learned reader, what remains to be done will rather be a work of ease and amusement, than of difficult and doubtful disputation.

For, if the notion of a *vacuum* be unsupported, and false in itself, nothing that is advanced in the mathematical philosophy, relating to *physical causes*, can possibly be right. Where that philosophy has mistaken or misrepresented the nature of these causes, it will be found inconsistent either with itself or with nature, and most probably with both: so that to detect the falsehood of it, we shall have nothing to do, but to compare it with itself, and with those notions of the natural world, with which our senses and experience will furnish us. In this disquisition, we shall have in review before us, a great variety of useful and curious experiments, which cannot fail of giving some entertainment, to a mind that hath bestowed any of its attention upon such subjects.

As

As my concern at present is barely with *physical causes*, no reader can be so absurd as to suspect, that I am aiming at the demolition of all that is now called by the name of *natural philosophy*, without doing me a manifest injustice, and betraying his own want of knowledge. The doctrine of *unmechanical causes*, though the forwardneſs and indiscretion of some adventurers may have loaded it with a much greater weight than it is able to bear, does yet make but an inconsiderable part of the established philosophy; and if it should hereafter give place to some more natural account of things, the remaining parts will always retain their present value. Such a work as that of professor S' Gravesande, will deserve the admiration of the ingenious, so long as the world lasts; and that man must have but an indifferent relish for the sciences, who is not greatly delighted with the discoveries and improvements he may there meet with, in *mechanics*, *optics*, and *astronomy*. I speak this in much sincerity: and it is intended to obviate any prejudices that might be raised against my design, either wilfully or by mistake. To give offence, is no part of my design; and I am unwilling, that any

well-designing person should think me to be possessed by a spirit of detraction, while I am conscious to myself it is far from me, and that I write upon much higher motives. I am encouraged therefore to hope for the attention at least, if not the favour, of all candid men and lovers of physical truth, while I inquire into the sense and merit of those *causes*, by which the Author of nature is now supposed to direct the natural world.

First then, let us inquire, what kind of force or agency Sir Isaac Newton and his followers would have us understand by the terms *attraction* and *repulsion*.

That *attraction* hath been called in for the explication of natural appearances, both great and small, every person must know, who has either heard or read any course of physical lectures delivered in English within this last century: it is looked upon as a principle, not to be approached without a degree of reverence, because the great Sir Isaac Newton thought proper to make use of it: but if the word should have no fixed meaning, and should itself want an explication, it will explain nothing at all; it will be a word without an *idea*: and if we apply it to any particular case, we shall explain,

as

as the phrase is, *ignotum per ignotius*, "a thing *unknown* by another that is *less known*." The word, if strictly taken, signifies a *drawing* or *pulling* of one body toward another: but as every science hath a liberty of adopting its own terms, provided it adds such a definition as will keep them clear of ambiguity, I shall spend no conjectures upon it, but try if I can settle the three following questions, upon the best authority that is to be had—first, *where* attraction is seated? for example, whether it be in the earth, or in the stone that falls down to it, or in both, or in neither, but in some substance exterior to both? secondly, whether it is to be understood as a *cause*, or as an *effect*? and thirdly, whether it be a *material* force, or an *immaterial* one? under which heads, all that need be said upon the subject may easily be reduced.

The principal species of attraction, being that of *gravity*, is described by Sir Isaac Newton in his 5th definition as a *centripetal force*, whereby bodies are *drawn*, *impelled*, or *tend in any manner* toward a centre: which definition is so far from giving any meaning to the word, that it rather seems to guard it, as it were, from having any meaning at all;

 there

there being a mixture of terms here, opposite in sense to one another, such as *attraction* and *impulse*. To say a body is *attracted* or *pulled*, is to place the power in that point to which the body is tending: to say it is *impelled* or *driven*, is to place the power *behind* it: but to say *both*, is to introduce two opposite forces, destructive of each other; which, in effect, is to say *nothing*. This definition, therefore, as it now stands, will give us so little help, that we must divide it into two parts; that is, we must distinguish *attraction* from *impulse* as things diametrically opposite, and see to which of these two Sir Isaac and his followers have inclined.

If we look forward in the *Principia*, we shall accordingly find, that *attraction* is the favourite term upon which all the learned author's reasonings turn; and that he supposes it to be a power seated *in the moved bodies themselves*, and in every *single particle* of which they are composed. What else can we understand by * *corpora trahentia*, "drawing bodies;" and, *corpora se invicem trahentia*, "*bodies that mutually draw each* "*other*," and † *sphæræ ex materiâ attractivâ constantes*,

* Lib. I. Sect. 11. † Ibid. Prop. 72.

constantes, "spheres composed of *attractive* "*matter*?" How again are we to estimate, as he directs, the attractions of bodies, "by "assigning to each of their particles their "*own proper powers**," unless the *power*, by whatever *name* he pleases to call it, be as truly seated in the particles themselves, as the force of resistance, or *vis inertiæ*, is supposed to be? And if the learned author of this doctrine had not really supposed the solid matter of the parts themselves to be endued with an active power, or principle of motion, he would not surely have taken so much pains to prove, that this power cannot be owing to any *æther*, or other matter, external to the moved body. For he sets it down as the result of his reasonings and experiments, that no species of matter can be *void of gravity*†; whence the conclusion is obvious enough, that no matter can act as the cause of gravity; unless the *effect* of gravity in some bodies, can be the *cause* of it in others; which is absurd. It remains, then, that the gravity of all bodies is owing to

* Assignando singulis eorum particulis *vires proprias*. Lib. I. P. 69. Schol.

† Lib. III. P. 6. Cor. 2.

to a *quality** residing in the bodies themselves; to which quality he gives the name of *attraction.* How much truth there is in the grounds of this conclusion, we shall see hereafter; when gravity, as an universal property of matter, is compared with experiment.

There are in the celebrated works of Sir Isaac, so many passages seemingly inconsistent with the doctrine above mentioned, and especially that portentous paragraph with which he has concluded his *Principia,* that I would proceed with all due caution, and not venture to fix such an opinion upon him, without taking some farther counsel, and inquiring *how*, and *in what sense*, this doctrine has been received in the judgment of others, who subscribed to his opinions, and understood them thoroughly.

Dr. J. Keil, who bestowed much pains in drawing out this principle of attraction into a theory, has the following assertion,— *Materiæ inesse vim attracticem, confirmat experientia;* "experience teaches us, that "there is *in matter* an attractive power." This he calls—*materiæ vis superaddita,* "a "force *superadded* to matter;" and again, *Inest*

* Hæc est *qualitas* omnium, &c. *Ibid.*

Inest materiæ potentia, quâ singulæ, ex quibus constat, particulæ se invicem attrahunt— "There is a *power in matter* by which all "its particles mutually attract one ano"ther*." So that in the constitution of all bodies, there is a composition of *matter* and *power;* and if their parts are found, either to adhere, or tend toward each other, we must ascribe it to a virtue in the parts themselves. If an heavy body falls to the earth, it is occasioned by a *vis* or *potentia* superadded to the matter of them both: than which nothing can be more express to the point; and it shews us, to a demonstration, how *attraction* was understood by Dr. Keil.

Dr. Frend, who endeavoured to solve the operations of *chemistry* by this principle, and was engaged in a controversy about it with some foreign writers, was of the same mind with Dr. Keil. In the defence of his lectures, he calls it—*principium attrahens, quod omni materiæ inest*—"a drawing principle "that resides *in all matter.*" And again he asserts—*Inesse immutabilem quibuscunque corporibus vim,* quâ *itidem in sese mutuò ferantur*—"that bodies are carried mutually to"ward

* Philos. Trans. No. 315.

" ward each other *by* an immutable *power* " *within themselves**.

Dr. Clarke, in his notes on Rohault, informs us, that "all those bodies will ascend "in water, which are less *attracted by the* "*gravity of the earth* than water itself†." Whence it appears, that, according to his notion of the affair, *attraction* is a quality residing in the matter of the earth itself; it being the *gravitas telluris,* to which the effect is imputed.

To these authorities I may add that of the ingenious Mr. Rowning; who, speaking of the attraction of gravitation, observes, in very plain terms, that the "*action of the* " *earth* upon bodies is exactly in proportion " to the matter they contain‡."

But, above all, the opinion of Mr. Cotes is to be regarded; and it is more to my purpose than any of the former. " We are to " believe," says he, " that the *action of the* " *earth* is composed of the joint *actions* of all " its *parts;* and therefore, that all terrestrial " bodies ought to *attract* one another with " absolute

* Philos. Trans. No. 331.

† Quæ *telluris gravitate* minus sunt *attracta.* P. I. ch. 22. § 15.

‡ Vol. I. p. 15.

"absolute forces, which are in a direct ratio "of the *drawing matter**."

All these authors then (and I might have added many others) who have followed the Newtonian hypothesis, declare, with one voice, that when a terrestrial body is so acted upon as to descend to the earth, the *drawing matter* of the earth itself is the *agent*; and it *acts* by a *power superadded* to it, which power they call *attraction*. All the other kinds of attraction, such as that of *magnetism*, *cohesion*, *electricity*, and *repulsion* the antagonist of them all, are to be understood in the same way: but I forbear to weary the reader's patience with any particular proofs of it. This, I remember very well, is the sense in which I myself, in common with other young men, understood the doctrine of attraction, when I was first initiated into these mysteries of natural philosophy: it is the sense in which I thought Sir Isaac did originally desire to be taken; and in which, I am confident, he is taken to this

* *Actio* itaque telluris ex conjunctis partium *actionibus* conflari censenda erit; atque adeo corpora omnia terrestria se mutuo *trahere* oportet viribus absolutis, quæ sint in ratione *materiæ trahentis*. See his Pref. to Sir Is. *Principia*, p. 3.

this day, by very many readers. I am now perfectly easy about it, being in the company of those writers, whose learning and candour, with regard to their author, have never yet been disputed.

CHAP. II.

An attempt to settle the Question, Whether Attraction *is the* Cause *or the* Effect?

IT will now appear very strange to ask, whether attraction be a *cause* or an *effect*; *action*, *force*, *power*, *&c.* having all been ascribed to it: but this inquiry will answer a very good purpose, and serve abundantly to convince the unprejudiced, that they, who brought this principle into fashion, did never yet know what to make of it.

Mr. Leibnitz, and many other learned mathematicians, were for exploding *attraction* at its first appearance: they even ridiculed it as unphilosophical, unintelligible, an occult quality, and a miracle; and absolutely denied its very existence. Observe therefore what a reply Dr. Clarke made upon the occasion—"It is very unreasonable to call

"attraction a miracle and an unphilosophical "term, after it has been so often distinctly "declared, that, by that term, we do not mean "to express *the cause of bodies tending to-"ward each other;* but barely the *effect* of "this cause, or the *phænomenon itself* dis-"covered by experience, whatever be or be "not the cause of it. Gravitation or at-"traction *in this sense* (he adds) is an actual "phænomenon in nature*." And again: "Philosophers therefore may search after "and discover that cause if they can, be it "mechanical or not mechanical: but if they "cannot discover the cause, is therefore "the *effect itself*, the *phænomenon*, or the "*matter of fact discovered by experience*, "(which is all that is meant by the words "*attraction* and *gravitation*) ever the less "true†?" Mr. Leibnitz objected to *attraction*, as to a *cause* occult and unphilosophical: Dr. Clarke answers him, by denying it to be any *cause* at all; for that it means nothing more than the bare *effect*, or *phænomenon* of a *tendency* in one parcel of matter toward another. And if this were all, who could take any offence at it? For that there is such a tendency, experience will indeed

* P. 355. † P. 367.

indeed convince us; and there are few astronomers who will not allow of it, even in the heavenly bodies themselves. But then the authority, to which this author has referred us, is no way to be reconciled with his account. The words of Sir Isaac are these: "I use the word attraction, only in "general, to signify the *force by which* "bodies *tend* toward each other*." Dr. Clarke assures us very positively, and desires he may not be misunderstood, that when bodies are said to be *attracted* or *gravitate*, nothing farther is meant, but that they are found by experience to *tend*: whereas Sir Isaac affirms, in the very words to which he has referred us, that attraction expresses that *force* in general *by which* they tend; and these two are as distinct as a cause and an effect can be; just as different, as is the *tendency* of a bullet toward the mark, from the *force* of the gunpowder, *by which* it is sent from the piece. And the following words are sufficient to prove, that notwithstanding what Dr. Clarke might think it convenient to say to Mr. Leibnitz, Sir Isaac did not publish his attraction of gravity to the world under the notion

* Opt. Q. 23.

notion of an effect—"It is enough," says he, "that *gravity* really exists, and *acts* according to the laws we have laid down *;" which an *effect*, I think, can never be said to do, without a childish abuse of language.

Let us next examine the opinion of Mr. Cotes, who thus appeals to his adversaries, in behalf of the Newtonian gravity—"Would you call gravity an *occult cause*, because the cause of gravity is occult, or not yet found out?" No, certainly I would not: for if its *cause* remains yet to be discovered, I would have observed the caution given by Dr. Clarke, and have called it an *effect*. For if gravity be a physical cause, we have already gained our purpose, and the science of physics does not require us to look for another. If it be a cause of so mysterious a nature that no physical account can be given of it, it must be classed among those occult qualities, which the scholastic philosophers affirmed to have a real existence, though they were unable to give any farther account of them. We have the authority of Mr. Cotes, however, that gravity is a *cause*, which was just now affirmed to mean nothing

* Satis est quod *gravitas* revera existat, & *agat* secundum leges a nobis expositas. *Princip.* p. ult.

nothing but an *effect;* and the adversaries of this philosophy were charged with the *unreasonableness* of a contrary supposition. From what this author hath written, it appears he never suspected gravity to be any thing but a cause, even the most simple of causes, beyond which human knowledge cannot possibly penetrate—*ubi ad causam simplicissimam perveneris* (such as he supposes gravity to be) *jam non licebit ulterius progredi**. He thinks there is a concatenation of physical causes in the world, some compounded, others simple and primary; but *gravity* he places among the *causas simplicissimas*, and *causas per phænomena comprobatas;* which latter expression sets him in a direct opposition to Dr. Clarke, with whom attraction and gravity mean nothing but the bare effect or phænomenon itself: here, it is the *cause* proved *by the phænomenon.* And it should be remembered, for the justification of Mr. Cotes, that he wrote in the year 1713, Dr. Clarke in 1717.

Dr. Desaguliers will inform us, that "*attraction* and *repulsion* seem to be settled "by the great Creator as first principles "in nature, that is, as the first of *second* "*causes;*

* *Princip.* Pref. p. 9.

"*causes*; so that we are not solicitous about "*their* causes, but think it enough to de-"duce other things from them*." This confirms the reflection I made a while ago; that attraction is a cause, of which no account can be given; and that it serves to keep us under the same ignorance with the occult qualities of the schools. It was for this reason only, that the learned men of the last age remonstrated against it with so much earnestness; and Sir Isaac, in order to remove the offence it had given, took the matter a second time into consideration. When he viewed it in a physical light, he concluded, from some particular experiments, "that there are *agents in nature* able to "*make* the particles of bodies stick toge-"ther by very strong attractions; and that "it is the business of experimental philoso-"phy to find them out;" that is, to find out those *agents of nature*, which act as the immediate *causes* of this *attraction*. By which remarkable concession, Sir Isaac himself, who elsewhere makes attraction a *force*, and gravity an *active principle* †, has reduced them both to *effects*; encouraging us, at the same time, to inquire experimentally after those

* Phil. Transact. No. 454. † Opt. p. 376.

those agents of nature, by which these effects are brought about; while Desaguliers, his disciple, lays down attraction itself as the *first of second causes;* and Mr. Cotes assures us, that if we get so far, *jam non licebit ulterius progredi.*

If we ask the opinion of Dr. Friend, he will tell us, gravity is an effect, and attraction is the cause of it. "This *attraction*" (which he had just before called the *force of gravity*) "they may, if they please, call "an occult quality; and I believe it will "always be occult:" yet, in another part of the same discourse, he says, "In ex-"plaining this gravity, which is evident to "sense, Newton hath far exceeded all other "philosophers; having demonstrated it to "arise from an *attractive force*, which dis-"perses itself far and wide through all "matter *." From which passages, we may learn these three things: first, that gravity and attraction are the same thing †, because the author,

* Attractionem hanc (scil. *vim gravitatis*) si ita lubet qualitatem occultam nuncupent, & erit, credo, semper occulta.—In hâc quidem gravitate *explicandâ*, quam sensu percipimus, longissime omnium processit Newtonus; eam quippe *a vi attractrice* quæ per omnem materiam se undequaque disseminat *oriri* commonstrat. Ubi suprà.

† See the passage quoted from Dr. Clarke at p. 62, 63.

author, speaking of the *vis gravitatis*, calls it—*hæc attractio.* Secondly, that attraction is an *occult quality*, and always like to remain so. Thirdly, that *gravity* is *best explained by attraction;* though, by his first supposition, they are the same thing; and then gravity is best *explained by itself:* by the second, attraction is allowed to be an occult quality, and he believes it will always remain so. Which doctrine comes out just as it should do; for, to explain any thing by an occult quality, is to explain it by itself; and, in this absurdity, the *causes* proposed by the mathematical philosophy will all be found to terminate.

How opposite to those of this last-named author, were the sentiments of the celebrated M. Maupertuis, who thus apologizes to the French academy in behalf of the Newtonian attraction: "Many people," says he, "have "been disgusted by the word *attraction*, "expecting to see the doctrine of occult "qualities revived again in natural philoso- "phy; but, in justice to Sir Isaac Newton, "it should be remembered, he has never "considered attraction as an explanation of "the gravity of bodies toward each other; "he has frequently warned us, that he em-

 "ploys

"ploys this term, not to signify a *cause*, but "only an effect*." Therefore, in the judgment of this learned man, whosoever recommends attraction to us as a physical *cause*, or an *explanation* of effects, revives the doctrine of occult qualities.

Lastly, let us hear the opinion of Mr. Rowning, a writer who has done much service to the public, by giving us a regular treatise upon natural philosophy in all its branches. But, alas! we shall find him to have fallen into the same inconsistency with the other writers who went before him; which I would impute wholly to the perplexed condition of the subject, and not to any intention of deceiving in the author. "It is to be observed," says he, "that when "we use the terms *attraction* or *gravitation*, "we do not thereby determine the physical "cause of it, as if it proceeded from some "supposed occult quality in bodies; but "only

* Le mot d'attraction a effarou hé les esprits; plusieurs ont craint de voir renaître dans la philosophie la doctrine des qualites occultes; mais c'est une justice qu'on doit rendre a M. Newton, il n'a jamais regardé l'attraction comme une explication de la pesanteur des corps les uns vers les autres, il a souvent averti qu'il n'employoit ce terme que pour designer un fait, & non point une cause. Vid. *Astron. Phys.* par Mr. *de Gamaches*, p. 348.

"only use those terms to signify an effect, "the cause of which lies out of the reach of "our philosophy. We may say that the "earth attracts heavy bodies, though at the "same time we are wholly ignorant whether "this is effected by some power actually "existing in the earth or in the bodies, or "external to both *."

Now, although *attraction* be an unhappy word by which to express an effect, yet if Mr. Rowning were consistent with himself in this matter, and carried the thing no farther, it would be well enough; but the contrary will soon appear, from a few short remarks upon this passage. *When we use the terms attraction or gravitation, we do not thereby determine the physical cause of it.* Of what? of attraction? *that* is not the thing required. We only desire to know, whether attraction really exists in nature, as a *force* or active principle; and whether we are to understand it as a *cause* of natural effects? or whether it be barely the *phænomenon* of a tendency or motion, the cause of which is yet to be sought after? It can never be expected, that the word *attraction* should be expressive of its *own cause;* especially

* Vol. I. p. 17.

cially if it be one of Mr. Cotes's most *simple of causes, and such as hath no dependence upon any other* *. The complaint is this: that attraction is proposed to us as an effect; but, if once admitted, it is thenceforward forced upon us as a *cause;* as a solution of every difficulty; while attraction itself is the greatest difficulty of all. That it is applied as a cause by Mr. Rowning, I shall shew hereafter: that it is not to be understood as an effect, may be proved from his own definition of it. "Matter," says he, "has also certain *powers* or *active principles*, "known by the names of *attraction* and *repulsion*, impressed upon it by the author "of its being, for the better *performance of the offices* for which it was designed †." If attraction, as the author says elsewhere, be a term used only to signify an *effect*, how comes it to be here described as a *power* or *active principle*, which are appellations utterly repugnant to the notion of a natural *effect?* Can an effect *perform offices*, and be *active* toward the production of an effect?

* Dantur certè primariæ corporum affectiones, quæ *quoniam sunt primariæ*, non pendent ab aliis. *Ubi sup.*; a piece of reasoning altogether scholastic.

† *Ibid.* p. 12.

effect? that surely must be the work of an agent or physical cause; and attraction must undoubtedly be taken for such, if it can be proved to perform any physical offices. But, says Mr. Rowning, "we are "wholly ignorant whether this is effected by "some power, actually existing in the earth, "or in the bodies, or external to both." And here he seems to have forgotten his own definition of attraction, it being a *power impressed upon* matter; others say, it is *in* the matter, and that the point has been *demonstrated.* But, if after all this we are wholly ignorant, whether it be within the matter, or without it, the obscurity of the whole becomes invincible, and attraction can serve only to raise a dust.

Truth, it is said, is not to be spoken at all times; but sometimes one cannot proceed a step without speaking it, and that is my case at present. Attraction, then, as Mr. Rowning and others have defined it, is an *occult quality*, an *ισχυς, δυναμις, affectio, facultas naturalis, vis insita*, or any thing in that way. But to avoid the imputation of this, some after-thought is generally added, to take off, as it were, and qualify the sense of their definition; which renders the

case

case still worse. For if you assert positively, that matter has an active principle or power *in it;* and afterwards confess, you cannot tell *what* it is, *where* it is, nor the *manner* in which it produces any single effect, or whether it produces any effect at all; then, if ever there was an occult quality maintained in the schools, attraction must be such a quality; and Dr. Friend has allowed us the liberty of so understanding it.

But I promised to shew, that although Mr. Rowning be in doubt what to call his attraction, yet in practice he applies it, not as the *phænomenon itself*, but as the *cause* of it, and for the purposes of *explanation*.— "The rise of the water in capillary tubes," says he, "is manifestly owing to the attrac- "tion of those particles of the glass, which "lie in the inner surface of the tube im- "mediately above the water *." In his account of which experiment, we have two things clearly distinguishable one from the other: the *rise of the water in the tube*, and the *attraction of the particles that lie in the inner surface of the glass*. The former is the effect manifest to sense; the latter is the cause to which it is manifestly owing. If it should

* Vol. I. p. 13.

should be suspected that I misunderstand him; then, I say, attraction must be either the cause or the effect; if it be the effect, then to affirm that the rise of the water is manifestly owing to attraction, is but to say in other words, that *the effect is manifestly owing to the effect.* If it be taken for the physical cause, and I should deny the reality of its existence, how would you prove it? you will refer me perhaps to the phænomenon, for that is the common way of reasoning, and tell me I cannot help seeing it. But *attraction* is not the phænomenon; it is Mr. Rowning's *explanation* of it. The phænomenon, evident to sense, is only the rising of the water; the *attraction of the glass,* not evident either to sense or reason, is set down as the cause to which it is manifestly owing: and this cause, as the author hath affirmed in another place, is a term used only to signify an effect.

The nature of attraction is such, that we have succeeded but very indifferently in this part of our inquiry, as I could plainly foresee we should. The subject is involved in an obscurity, either studied or unavoidable; and in all the passages I have been able to collect and compare, there is something that

appears like a slight of hand, whereby the *effect* is shifted into the place of the *cause.* As I am unable to draw any doctrine from the whole with precision, it will be best to introduce the authors giving their verdicts in their own words, and leave the reader to his own judgment.

Sir *Isaac Newton.* "Gravity exists and "*acts.*"

Dr. *Friend.* "In *explaining* gravity, "*Newton* has demonstrated it to arise from "an *attractive force.*"

M. Maupertuis. "It should be remem- "bered, in justice to Sir Isaac Newton, he "has never considered *attraction* as an *ex-* "*planation of gravity.* He considers it not "as a *cause,* but as an *effect.*"

Mr. *Cotes.* "Gravity is the most simple "of *causes.*"

Dr. *Clarke.* "It has often been distinct- "ly declared, that by the term *attraction,* "we do not mean to express the *cause* of "bodies tending toward each other, but "barely the *effect,* the *effect itself,* the *phæ-* "*nomenon,* or *matter of fact.*"

Dr. *Desaguliers.* "*Attraction* seems to "be settled by the great Creator as the *first* "*of second causes.*"

Mr.

Mr. *Rowning*. "When we use the term "*attraction*, we do not determine the physical cause of it, but use it to signify an "*effect*: nevertheless, to attraction effects "are *manifestly owing*."

Sir *Isaac Newton*. "There are *agents in* "*nature* able to make the particles of bodies "stick together by very strong *attractions*, "and it is the business of experimental philosophy to *find them out*."

Dr. *Desaguliers*. "We are not solicitous "about the *cause of attraction*."

Dr. *Friend*. "I believe *attraction* will "always be *occult*."

This is the result of my inquiry: and if any person should be so inclined, he is welcome to lay all the blame upon my want of understanding. But, if these learned men, who are all vindicating the self-same principles of philosophy, had no clear ideas of what they affirmed, and could not understand *one another*; it is no wonder, if the world should be at some loss to understand *them*.

CHAP. III.

Attraction, a material *force in the judgment of some authors; an* immaterial *force in the judgment of others; and sometimes both* one *and the* other *in the judgment of the same author.*

WE have yet a third question to settle, *viz.* whether *attraction* be a *material* force, or an *immaterial* one? and here we shall have the same scene as before; this point being left equally undetermined with the former. Indeed nothing can be more evident, than that Sir Isaac Newton, great as he was, hath offered to the world his thoughts on a question of much importance, and taken *both sides* of it. It is disagreeable to me to say this; but it must be said, because it is certainly true; and I cannot go forward without saying it. This, as we shall find, has divided his followers; and their disputes with each other in regard to first-principles and fundamentals, have as great an appearance of fallibility and uncertainty, as other disputes used to have, before

fore the science of natural philosophy was enriched with demonstration: of which I shall exhibit a notable instance, from the writings of the celebrated Mr. Maclaurin, and his antagonist, the author of an *Inquiry into the Nature of the Human Soul.*

But first let us attend to Sir Isaac himself. There is a passage in his *Optics*, wherein he allows, that what he imputes to *attraction* may be performed by *impulse* *. Dr. Clarke, in his notes on Rohault, cites this passage; and lest we should take the impulse here spoken of, to be that of some intervening *matter*, he inserts, by way of comment—*non utique corporeo*—† declaring, that this *impulse* is *not corporeal*; or, in other words, that it is not the impulse of any material agent. We have the same sentiment from him upon another occasion:—" It is now " allowed on all hands, that gravity does " not depend on the action of the air or " *æther*, but is a primigenial, innate, and " unchangeable affection of all matter ‡." This is in answer to the great Dr. Wallis, who was of another mind. He suspected that

* Page 351. † Page 51.

‡ Verùm cum jam in confesso sit, gravitatem non ab aere *ætherève* pendere, sed esse primigeniam, connatam, immutabilemque materiæ *affectionem*, &c. p. 61.

that gravity, though usually taken for a primary quality, might be owing to the *percussion* of some impelling matter, and proposed a shrewd case to countenance his opinion; but I forbear to say any thing farther of it in this place.

Mr. Rowning, who has laid down the received philosophy with as much diligence and fidelity as any man, hath affirmed nothing so expressly, as that "these *dispositions* in bodies (such he calls gravitation, "attraction, &c.) are not the result of any "mechanical cause whatever, that is, such "as may arise from the action of any material substance*." And he has treated his mathematical readers with a demonstration, proving the impossibility of it. Professor S. Gravesande, from whose great abilities we might have expected something more satisfactory, unhappily fell into the same way of reasoning; and gave a geometrical demonstration, (as he thought,) that the spherical figure of a drop of water cannot be occasioned by the *equal pressure* of any fluid medium.

* Pref. p. 6. Mr. Cotes hath affirmed the same, in his preface to the second edition of the *Principia—Gravitas—ex aliis corporum affectionibus atque adeo ex causis* mechanicis *originem* non *habet*. p. 9.

medium. More authorities to the same purpose might easily be produced; but this doctrine hath been so largely and confidently maintained by so many writers, that I must have the assent of the learned, if I set it down as a doctrine of Sir Isaac Newton.

But then, on the contrary, it is to be remembered, that this introducing of immaterial impulses into the world of matter, first raised a clamour against his philosophy, as tending to revive all those occult qualities, which had been so happily banished, but a while before, from all books of natural philosophy. To obviate this, and to *shew*, as the author expresses himself, "that he did "not take gravity for an essential property "of bodies," *he added a question concerning its cause**. This *cause* he supposes to be a *subtile ætherial medium—readily pervading all bodies—expanded through all the heavens—causing the* gravity *of those great bodies* (the sun, planets, comets, &c.) *towards one another, and of their parts toward their bodies*—and such as *may suffice to* impel *bodies from the denser parts of the medium toward the rarer with all that power which we call gravity.*

* Opt. Advert. II.

vity *. This, I say, is proposed as a *material cause*. For, is it not a *medium*, capable of *rarity* and *density*, subject to a kind of *vibrations* or pulses? and an *immaterial medium* would be an *ens rationis*, a philosophical spectre, a contradiction in terms.

Here, then, we have two different systems of philosophy. According to the former of them, all the operations of nature are conducted by the means of *unmechanical* and *immaterial impulses* in a *vacuum;* but, according to the latter, they have as their immediate *cause*, an *æther* expanded through all the heavens: and he that shall take up either with the one or the other, or with the one against the other, will have Sir Isaac Newton on his side; but whoever shall assume them *both* as true, will bring himself into great distress and difficulty.

This was the fate of the ingenious Mr. Maclaurin, a learned and elegant writer, who undertook a formal defence of the Newtonian hypothesis against all the objections that had been made to it; and was well qualified, if any man could be so, for the undertaking. He understood his subject perfectly; and was sensible he could never do justice

* See Opt. Q. 18, 19, 20, 21.

tice to the *Principia*, without banishing all material causes from the heavens. This he attempts to do, though it is frequently with some reserve, in several parts of his treatise, particularly in the following words: "as "for a more subtile medium than the air, "no experiments nor observations shew, "that there is any here, or in the celestial "spaces, from which any sensible *resistance* "can arise *." Mr. Maclaurin was very well inclined to admit a material agency in subordination to the first cause †; but this false doctrine of *resistance* tied up his hands, otherwise his work might have been all of a piece. As it stands now, the most valuable passages in it are so many contradictions to all the rest. After what he has said above, who would expect to hear him reflect upon "others, who, while they overlook the in-"termediate *links* in the *chain of causes*, "and hastily resolve every principle into "the *immediate influence* of the first cause, "impair the beauty of nature, put an end "to our inquiries into the *most sublime parts* "*of philosophy*, and hurt those very interests

 "they

* Page 294.

† This is very manifest from the 14th section of his last chapter.

"they would promote *." They do so most undoubtedly: but hath not the mathematical philosophy this tendency? doth it not oblige us to deny, against reason and our better knowledge, that *any experiments or observations shew that there is a medium more subtile than air?* hath not Mr. Maclaurin himself denied it in these very words? And elsewhere, in the most categorical terms, he hath asserted an absolute *vacuum*:—"Sir "Isaac Newton's philosophy," says he, "has "shewn, that not only there may be, but "that there *actually is a vacuum*—that mat-"ter appears to occupy but *a very small por-"tion* of space †." If this should be true, what becomes of his *chain of causes?* for, if there be no medium concerned as a secondary cause in the motion of the planets, &c. it follows unavoidably, that there must either be inherent and self-moving *powers in matter*, or that the influence of the first cause must be *immediate*, for there is nothing else remaining; and then Mr. Maclaurin's chain will consist but of one link. This is the opinion which, he thinks, must *put an end to our inquiries into the most sublime parts of philosophy*. And lest it should be suspected that

* Page 95. † Page 77.

that Sir Isaac's method of philosophizing has introduced *immaterial powers* and occult qualities, we are assured by this author, "that "he does never affirm or insinuate that a "body can *act upon another at a distance*, "but by the intervention of other bodies *." But his zeal hath carried him a little beyond the truth; the thing he here denies, being much more than *insinuated* in these words: "Have not the small particles of bodies certain *powers*, virtues, or forces, by which "they *act at a distance*, not only upon the "rays of light—but also upon one another, "for producing a great part of the phænomena of nature? for it is well known that "bodies *act upon one another* by the *attractions* of gravity," &c. †

Attraction, as a power acting *at a distance*, is here left in full possession; not a syllable being inserted, as I can find, concerning the *intervention of other bodies.* If this intervention were admitted, how would it agree with what Dr. Clarke has so frequently inculcated throughout his notes on Rohault's physics: He sticks not to assert an *impulsus non utique corporeus*, and an *actio causæ cujusdam immaterialis—per interjectum ali-*

 quod

* Page 109. † Opt. Q. 31.

quod intervallum, &c. see p. 50. Besides, the sense of the whole passage would be overthrown by Mr. Maclaurin's supposition; for, if other bodies intervene, then attraction will not be a power acting *at a distance*, but by a *communication* of bodies that are in contact. The author (Sir Isaac Newton) does indeed inform us, a while after, that he uses this word to *signify only in general any force**, &c. But this does not alter the case; for, let it be a force *in general*, yet it hath this *particularity* in it, that it *acts at a distance*, which is the nature of an *occult quality*, and is the very thing that has all along been objected to. And though Mr. Maclaurin hath taken great pains to get handsomely rid of this unintelligible power, yet is the existence of such a power absolutely necessary upon his own principles. Sir Isaac, he says, hath shewn, that there *actually is a vacuum*, and that the *parts of matter are actually divided and separated from each other*: after which it would be strange, indeed, if they were to *act* otherwise than in this state of *division and separation*, that is, *at a distance*. When he supposes other matter to *intervene*, till the action will consist with mechanism, he apologizes

* Opt. Q. 31.

apologizes for a *vacuum*, at the expence of the principle itself; which, by this means, is turned into a *plenum*, whether the author was aware of it or not.

How unseasonably, therefore, was it observed by Mr. Maclaurin, that "possibly "some unskilful men may have fancied, that "bodies might attract each other by some "charm or *unknown virtue*, without being "impelled or *acted upon* by other *bodies* *;" for, if this was not a fancy of Sir Isaac Newton himself, in common with some of the most skilful of his followers, the plainest English can have no meaning. I know very well, his writings contain many passages which seem to have a contrary meaning; and his disciples find such an advantage in this, that they have an answer ready upon all occasions. For example, if you suppose the world to be ruled by a subordination of material instruments, in opposition to Sir Isaac's vacuum, then you are told there is *no medium more subtile than air*; that the heavens are *void of all sensible matter*; and it is demonstrated against you *geometrically*, that attraction *cannot arise from the action of any material substance whatsoever*. If you should

* *Ubi sup.*

lay hold of this, and object to attraction as a principle *occult* and *unphilosophical*, then it is only the *fancy of some unskilful men;* and Sir Isaac Newton has *plainly signified, that he thought that those powers arose from the impulses of a subtile ætherial medium that is diffused over the universe**. Thus you are confuted either way; and your reasoning is represented as *crafty*, *disingenuous*, and *unworthy of a philosopher* †.

By this artifice, Mr. Maclaurin would have quieted all our scruples; but seems to have miscarried in the attempt, having been obliged to contradict his author *in terminis;* and, I may add, *himself* also; as it hath been fully proved against him by Mr. Baxter, the author of an *Appendix to an inquiry into the nature of the human soul.*

There are two different modes of philosophy before us, both of which have Sir Isaac Newton at the head of them. Mr. Maclaurin, by espousing them *both*, fell upon various contradictions. Mr. B— is more cautious; and hath written with some warmth on one side, against Mr. Maclaurin who is on both sides. Where the latter hath really laid himself open, he makes good use of the

* *Maclaurin*'s Phil. Disc. p. 111. † See p. 110.

the opportunity; without considering where, and upon *whom*, his censures will at last be fixed*. He is clearly of opinion, that the material causes, occasionally introduced by his adversary, are utterly inconsistent with what is established in the *Principia;* and is therefore a declared enemy to all *subtile matter*, even to that *æther* of Sir Isaac, for which Mr. Maclaurin hath pleaded as handsomely as the nature of the thing would admit. "Men of leisure (he says) have "amused the world with wrangling and "contest—by a succession of *subtile mat-*"*ters* from the earliest times.—But it re-"quires only plain sense, and a love of truth, "to see through the *imposition* †. It is in-"jurious," he thinks, "to that great man's "reputation, to bring in his authority for "a thing which he asks only by way of a "*query*, as if he had been positive;" and that it is "an ill office done to his memory." But this is a reflection, which, in my humble opinion, his adversary did not deserve: and it should be considered in his vindication, that though a *query* may shew Sir Isaac not to have been *positive* about the *manner* in which his *medium* acts; most certainly it doth

* See *Append.* the note at p. 113. † P. 66.

doth also shew, he was not positive that no such thing existed; especially as he hath mentioned an experiment to prove the existence of a subtile matter which has never yet been answered*. By what authority then is this writer so positive? and what will be the consequence of it, when it *requires only plain sense, and a love of truth*, to see that he is disputing for one half of Sir Isaac Newton, against the other half? The authority of that great man is indeed like to be killed, not by the malice of his enemies, but by the kindness of his friends; if some of them think an *ill office is done to his memory*, while others think they are offering the only expedient vindication of it.

This learned author presents us with the *attraction of cohesion*, as *an universal phænomenon, that ought to silence the advocates for material causes in all cases*†; and *promises to be silent, if all the philosophers upon earth can account for it, otherwise than by the power of the Deity immediately interested, &c.* He judges it *very unartful to suppose the Deity employing one part of matter to move or direct another part of it*‡, though we see it

* See *query* 18. † P. 62. ‡ P. 49.

it done every day of our lives.—And that no *subtile matter* can act as the *cause* of *gravity*, unless it *knows* what it is doing*. These, and some other *difficulties* of the same size, he thinks to be so great that *there is no subterfuge*†: though it might easily be shewn, there is not one case of any concern rightly stated throughout his whole book; and that every article he has built upon is confuted by experience. These considerations, I presume, tempted Mr. Maclaurin to pass sentence upon his whole system in these words—"He has done this valuable service, "that while he vainly imagined he im-"proved or completed it, he really opened "up the fallacy, and reduced it to an ab-"surdity."

I proposed it as a question, whether attraction be a *material* force or an *immaterial* one? and we have now consulted those writers who ought to have settled the point for us. If Sir Isaac hath really *established* any thing on either side, in regard to physical causes, it is astonishing his followers have not fixed upon it, and recommended it to the public with one consent; especially if there be any thing of importance depend-

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* Page 117. † *Ibid.*

ing upon it. But if, on the other hand, the sentiments of their master have given occasion to these disputes, and his writings have furnished them with arguments on both sides; then he himself is chargeable with some inconsistency; and a general agreement among them, in such a case, would be as much to be wondered at. That this latter is the true cause of all their disagreement, will be evident to any reader, who is not so far influenced by the current authority, as to be deterred from making use of his own reason. For if you learn from one page, that it is part of the business of a philosopher *to unfold the mechanism of the world* *; and that an *ætherial medium* may *suffice* to *impel* bodies †; in another it is hinted to you, that the small particles of bodies may have certain *powers* by which they *act at a distance—by attractions* ‡. If you are informed in one place, that when the rays of light are reflected from the second *surface* of a glass laid upon an *exhausted receiver*, this *total reflection* ought to proceed from the *vigour* and *density* of the *medium beyond the glass* §: only observe where the same experiment is mentioned in another place,

* Opt. 3d *edit.* p. 344. † Q. 21. ‡ Q. 31. § Q. 19.

place, and you will find, the light is now *drawn* back, and that by the *power of the glass*, there being *nothing else to turn it back**; though a while ago there was a *medium* to perform this, endued with *vigour* and *density*. It is suggested, that this *medium* may act upon light so as to *reflect* and *refract* it†; and that the *light* in its turn may re-act upon the medium so as to *stir up vibrations* in it: but soon after, it becomes "inconceivable how two æthers can be "diffused through all space, one of which "acts upon the other, and by consequence "is re-acted upon, without retarding, shat-"tering, dispersing, and confounding one "another's motions‡."

I could multiply instances of this sort, wherein the celebrated author has pulled down with one hand, what he had built up with the other: but if men will dare to use their own reason, as I said before, they may easily observe these things for themselves.

If we go from Sir Isaac to his followers, there the confusion will be still more manifest. Drs. Clarke, Derham, Keil, Friend, Desaguliers, Mr. Cotes, Mr. Rowning, &c. instruct

* Q. 29. † Q. 18. 20. ‡ Page 339.

struct us, that *matter* has *powers, forces, principles, affections, properties, impressed* upon it, *superadded* to it, or *inherent* in it; and that God, when he created the world, *inspirited the materials of it with an active quality.* This was the original doctrine of the mathematic philosophy, and the sense in which it was first embraced by the learned. As it gave birth to many ill-favoured reflections, it is now almost out of fashion; and Mr. Maclaurin rises up to vindicate Sir Isaac, by a substitution of his subtile *æther,* as the mechanical and immediate cause of all that had been falsely imputed to *attraction* by *unskilful* men. This stirs up the indignation of another; who, out of the highest regard to the *memory* of Sir Isaac, pulls this vindication of him all to pieces, represents it as worse than none at all, rejects all *subtile matter* in the lump, and recommends the *immediate influence of the Deity,* as the grand discovery, and the only cure for all disputes. But, for his pains, he is instructed, in his turn, that his own labours have only *served to open up the fallacy of his scheme, and reduce the whole to an absurdity.* There have been heavy complaints, that the philosophy

sophy of Sir Isaac hath been *depreciated*, and *even ridiculed**. And is it not enough to discompose the muscles of an hermit, to see men thus notoriously contradicting one another, and all gravely pretending to *authority* and *demonstration!* They tell us, there has been a great *discovery* of late years in natural philosophy; it having been found at length, after the world had been in ignorance for many ages, that all matter is endued with *attraction.* If you ask them what they mean by it; it is—an innate virtue or affection of matter; while others affirm, matter can have no such affections. It is the most simple of *causes*, and an *effect*, the cause of which is unknown; it is owing to the agency of a *subtile medium;* and it is effected by the *immediate influence of the Deity:* and if you do not believe this principle, and make use of it to *explain* every thing, you are out of the fashion, and what you have to say will be very coldly regarded.

As we cannot possibly believe *all* these opinions, we are not bound to believe any one of them upon the bare *authority* of Sir Isaac Newton. If we are to receive one of his

* Philos. Difcov. p. 110.

his opinions in this way, why not another? the authority which is broken through in one article, will at least be questioned in every other. If it be said, we have reason to prefer some of his sentiments to others; then we are influenced, not by authority, but by reason or evidence; and hitherto I would willingly bring this matter. Reason and evidence must determine us at last, though the fame of Sir Isaac Newton were as universal now as that of Aristotle was formerly. His warmest friends take this liberty with him. Mr. Maclaurin rejects his immaterial powers *acting at a distance;* Mr. Baxter makes as free with his medium, yet is greatly displeased with his adversary for lessening Sir Isaac's authority. But they treat the public with some disingenuity, if they would overbear the judgment of others by that authority, which, as it appears from their own practice, hath had so little influence upon themselves. They choose their own sentiments, as inclination or passion directs; and then desire us quietly to rest upon the authority of Sir Isaac; though one of these has robbed him of his *attraction*, the other

of

of his *medium*; and thus, between them both, they have left us nothing to follow.

If the learned were but once persuaded, that God doth govern the natural world by a delegation of material instruments, which seems to have but *one* of the opinions of Sir Isaac, at least it was an opinion held by Mr. Maclaurin in his name; and could be brought to see any errors in the doctrine of resistance; something, I am convinced, might yet be done, either in this or the succeeding age, to render natural knowledge more serviceable to the people of all classes than it is at present; chiefly because the inquirers of these times would no longer have their hands tied up by an imaginary infallibility in those who have gone before them; the admitting of which has always been attended with fatal effects: they might then reject such principles as are manifestly false, and *put a stop to their inquiries*, and take advantage of the rest in common.

It is still believed, however, by very many, either that matter, though inert, is endued with active qualities; or that the influence of the Deity is immediate in the production of all natural effects. By the former of these positions, we allow to dead matter a

power that is denied even to God himself*: by the latter of them, we are directed to read nature backward; to begin where we ought to have ended; and, in support of such procedure, are obliged to annihilate the far greater half of the creation. I shall therefore go on to examine, how far these positions are supported by mathematical evidence.

CHAP. IV.

The Attraction of Gravity, *understood as an* universal Property *or* Quality *in the Parts of Matter, hath received no Proof from* Geometry.

WE have been assured from every quarter, that the modern doctrine of physical causes has all the evidence that can be desired from experiment, and is abundantly confirmed by the most strict mathematical reasoning. That this doctrine was deduced

* Omnipræsens est non per *virtutem* solam, sed etiam per *substantiam*: nam virtus sine substantia subsistere non potest. *Newt. Princip.* schol. gen.

deduced analytically from observation; then applied synthetically to the explication of the various phænomena: and its impregnability in these respects has been boasted of, I will not say insolently, but confidently enough, I am sure, by all its admirers, great and small, from the learned, who think it rests on the firm basis of geometry itself, down to our mere English mathematicians, who declare it as their opinion, that "*never* "*a philosopher before Newton ever took the* "*method that he did—that it is a mere joke* "*to talk of a new philosophy—and that in* "*these unhappy days of ignorance and avarice,* "*Minerva has given place to Pluto,*" meaning "Plutus*.

These pretensions, whether of the learned or unlearned, deserve a serious examination. Experiment is nothing less than matter of fact, which, if not misrepresented, is the best sort of argument in the world: and a *mathematical* conclusion, if deduced from real data, is not easily overthrown. Something has already been said of mathematical

 evidence,

* See the Preface to Emerson's Treatise on *Mechanics*. The book is very ingenious and useful in its way, and the Author appears to understand his subject; but when he decides thus magisterially upon philosophy in general, it is *sutor ultrà crepidam*.

evidence, in the former part of this Treatise; therefore I have the less to say of it in this place. And, indeed, very little need be said, if the theory of resistance be a fallacy, as I have fully proved it to be; for *that* is the thing generally aimed at by those who speak of mathematical demonstrations. It may, nevertheless, be useful to remark, that no physical principles whatever can possibly be collected from geometry. Every particular science hath principles peculiar to itself, and independent of every other. No example can be given of the contrary within the whole circle of the sciences. How absurd would it appear, if we were told of the musical principles of physic, the medicinal principles of the civil law, the grammatical principles of astronomy, &c. And mathematical principles of natural philosophy, if *physical causes* are supposed to be included, will be equally unnatural; as the most skilful mathematicians have been ready enough to confess. "Geometry," says Mr. Maclaurin, "can be of little use in natural philosophy, till data are collected to build upon *." These data, I presume, are to be obtained from natural philosophy, as a science circumscribed within its own proper bounds.

* Page 30.

bounds. A method of investigation, strictly physical, should first be submitted to; and the result of that be examined and settled, prior to all that can be done in geometry; the application of which may be of excellent use to illustrate and adapt to particular cases what hath gone before, but will add neither demonstration nor confirmation to it. For a geometrician can work with imaginary or hypothetical forces as well as with real ones; the operation will go on as smoothly, and the conclusion come out as readily in one case as in the other. No man seems to have been better persuaded of this, than Sir Isaac Newton himself. His followers, indeed, will assure us, he has undeniably proved one species of attraction to be diffused through the whole planetary system *. But the author himself knew better. He declares more than once, that the principles laid down by him in his demonstrative work, were not physical, but purely mathematical †, as the *title* implies: and with regard to gravity or attraction in particular, he is so far from pretending to have demonstrated the existence of any real physical cause under that term,

 that

* *Friend.* Chym. Lect. p. 180. † Page 356.

that his definition of it is so loose as to leave us quite at liberty about it. We may take it as a drawing, an impulse, or a tendency of any kind toward a centre. When he considered it physically, he thought a medium might suffice to *impel* bodies, and answer all the purposes of that attraction, which, as it stands in his Principia, is a cause barely hypothetical. Should it be imagined, that attraction, as a cause, power, or principle, had been established by demonstration, the author will be set in a very disadvantageous light, who could first *demonstrate* attraction, and then *inquire* about it.

But there is one circumstance that will put this whole affair out of doubt. It is well known, that the attraction supposed in the Principia, is mutual between all bodies whatsoever. If the earth attracts the moon, the moon in its turn attracts the earth; if the sun attracts the planets, the planets also attract the sun; and this attraction always follows the proportion of the quantities of matter in the attracting bodies. As a necessary consequence of this, the sun will be perpetually shifting its place, and be moved sometimes to this side of the common centre

of

of gravity, sometimes to that, as he happens to be influenced by a different situation of the planets *.

Now, I beg leave to compare this with what is said of an ætherial medium in the Treatise of Optics. This medium is supposed to be *rarest* at the body of the sun, but to increase in density through all the distances from the Sun to Saturn, and beyond; and that it may suffice to *impel* bodies from the denser parts of the medium toward the rarer, with all that power which we call gravity †. All this is very just: the pressure of such a medium will undoubtedly be greatest on *that side* of the planets which is turned *from* the sun; and all bodies will naturally be carried to that side where the pressure is weakest, that is, *toward* the sun. But what is become of the sun's *mutual gravity* in such a case? for, if he gravitates toward the planets, we must contradict this mechanical rule, and say, bodies will be impelled from the rarer parts of the medium toward the denser, without which, the sun, being already in the rarest part, must for ever be at rest. Sir Isaac

* Sol, pro vario planetarum situ, in omnes partes movebitur. *Princip.* p. 374.

† Q. 21.

Isaac either did see this consequence, or he did not. That he did not see the plainest consequences of his own reasoning, few will be ready to admit: if he did, he gave up mutual gravity to all intents and purposes; but this he never could have done, had he thought it to have been mathematically demonstrated.

I hope I shall not be misunderstood in this affair. It appears to me, that gravity is no property of matter, because it is not universal; and I have compared some passages, to shew it was not universal in the opinion of Sir Isaac himself, provided only he saw the consequence of his own reasoning, which will hardly be disputed. But while I am persuaded that the sun neither does, nor can possibly, gravitate toward the planets, for the very reason given by Sir Isaac Newton, I am far from denying that the planets tend toward the sun, and toward each other: it is highly reasonable, with some proper restrictions, they should do so; and experience, I believe, will convince any astronomer of the fact. As the world stands indebted to the genius of that great geometrician for this discovery, let the learned obtain from it what light they can in ascertaining

ing the phænomena, and let him him have all the honour of it. But never let it be a pretence for saddling us with occult powers in solid matters; if his followers make that use of it, they will gain no credit to their master in the end; and hitherto they have gained but little to themselves by it, as it must have appeared from what hath been said: in all which, I hope there hath been on my part no mixture of envy or prejudice, unless matters of fact, and plain argumentation, are so to be interpreted.

We are to conclude, then, that the attraction of gravity, understood as an universal property of matter, is void of all geometrical evidence. If Sir Isaac Newton hath left this affair undecided, no other geometrician, of this age or the next, is like to supply his defects; and yet every smatterer almost in natural philosophy is persuaded he can make it out against all opposition. The ground and reason of which mistake I apprehend to be this: that many of our geometricians, ambitious of dictating to us about the causes and first springs of nature, while their art can reach only to the *measure* of some of its *effects*, have not been careful to distinguish how far a mathematical conclusion will extend,

tend, and how far not. Hypothetical forces, or real ones, as it was observed above, will equally afford matter for an astronomer to work upon *. For example, if the moon, as she moves in her orbit, is imagined to be influenced by forces acting in lines which tend toward the centres of the earth and sun, then the different inclinations of her orbit to the ecliptic, the irregular motion of her nodes, her retardation about the quadratures, her acceleration about the conjunctions, &c. may follow by the rules of geometry. Upon these principles, Sir Isaac Newton is universally allowed to have accounted for the lunar irregularities with great sagacity; and, as an astronomer, to have left that matter in a much better state than he found it, though it is not yet perfected. But what these forces are in special, and in what manner they act; whether as an active immaterial virtue, exerted through a void space, *from* the centres of the earth and sun, or as a pressure of some etherial medium acting in lines *toward* those centres, none of his reasonings have determined

* Neque necesse putant, ut hypotheses istæ veræ sint, imo ne verisimiles quidem, sed sufficit hoc unum, ut calculum observationibus congruentem exhibeant. *Horrocc.* Op. Post. 179.

mined for us. So far from it, that we find his Principia inclining to one side, and his Physical Queries to the other. And I may appeal to the judgment of any ingenuous man, sufficiently versed in mathematical studies, whether the phænomena above mentioned may not arise from a pressure *behind*, as well as from an attraction *before*; and whether Sir Isaac's geometrical reasoning will not be as conclusive in the one case as in the other? How comes it then to have been published to the world, that "one species of attraction hath been undeniably "proved to be diffused through the whole "planetary system?" This having been no more proved by any of his arguments, than that one species of *impulse* or *pressure* is diffused through the whole planetary system; and for the truth of this, I may refer to the *definition*, where the terms *attraction* and *impulse* are taken indifferently, and are to be so taken throughout the whole book, otherwise this can answer no purpose as a *definition*. That some force prevails, and in such particular directions, is capable of demonstration; but the reasoning and observation, which only prove the existence of some force in general, will never demonstrate

that

that of attraction to be the force in particular: so that nothing farther need be said in this way. Let us now go on to experiment.

CHAP. V.

The Attraction of Gravity, understood as an universal Property *or* Quality *in the Parts of Matter, is not agreeable to* Experiment *and* Observation.

NO experience has hitherto shewn us, that what is called the *attractive force* of the sun and planets, is answerable to their quantities of solid matter. Their bulk, as computed from their respective distances and apparent diameters, is far from yielding a proportion of gravity so uniform as might have been expected. Gravity toward the earth proves to be much greater, in proportion to the bulk of the earth, than gravity toward the sun, or any of the primary planets. This seems to be a great difficulty in the hypothesis of gravity. But how easily is it reconciled, if we are allowed to alter the *density* of

of the heavenly bodies, and by this means bring their quantities of matter to an agreement with the hypothesis! The *fiat* of a favourite philosopher can so reduce the density of the solid matter in the body of the sun, that the density of the earth shall be *four times* greater, and then the attractive power of the sun shall exactly answer to his quantity of solid matter; and the same liberty must be taken with the other great bodies of the solar system. Their density must be accommodated to their attractive powers: then, if their attractive powers be taken for granted, their densities will pass for a *discovery*. Thus great men amuse themselves and the world by arguing in a circle, or proving the truth of a proposition by the conclusions they have drawn from it: for, unless you admit of this density, which, arbitrarily, and without any observations to support it, is accommodated to the hypothesis of gravity; that hypothesis will labour under a disagreement with observation.

That there may be some shew of experience, however, in all this, it is intimated, that the sun must needs be rarer than the earth, because of the immense heat of his body.

body *. But the planet Jupiter, whose body must be exceedingly colder than that of the earth, appears from his attractive power upon his satellites † to be much rarer than the sun, and Saturn rarer still, which circumstances are very unpromising; and if gravity be admitted here as the sole agent, we are conducted to a sort of philosophy that blows hot and cold against all reason and experiment. Descartes was of opinion, that the density of the planets must naturally increase as they are more remote from the sun; and surely this is more reasonable than the contrary: it being an observation, to the best of our knowledge, universally true, that bodies are rarefied by heat, and condensed by cold, the seeming rarefaction of ice not excepted.

That the gravity of bodies is, in all cases, as their quantities of solid matter, is rendered very

* Nam per ingentem suum calorem sol rarescit. *Princip.* p. 372.

† The method Sir Isaac made use of to investigate this mathematically, is laid down, in a manner as easy as the thing is capable of, by Dr. John Clarke, in his *Demonstration of Sir Isaac Newton's Principles of Philosophy*, 8vo. p. 301, &c. Consult also Mr. Maclaurin's Account, &c. p. 288, &c.

very doubtful, if not absolutely false, by some chemical experiments, and has been doubted of by persons of no ordinary skill in geometry and natural philosophy. Mr. Maclaurin, among the rest, thinks we can affirm this, only when we compare bodies of *of the same kind**.

Homberg's experiment on the regulus of antimony, and the success of it, is a thing generally known. He exposed some of this matter to be calcined by the great burning glass of the Duke of Orleans, and found it had gained in the operation one-tenth part in weight. Homberg made this experiment, and some others like to it, with the expectation of being able in due time to produce gold. But *truth* is of much greater value, and if we can produce any of that from it, let us leave all the gold to the adepts. Some relate the experiment thus: If a mass of regulus of antimony, of a pound weight, be pulverised, and calcined at the focus of a burning glass of a Paris foot in diameter, the weight of the mass will be increased by one-tenth; though,

* This agrees exactly with a definition given by *Plato*—*ωσπερ εν τω* Τιμαιω *τυγχανει γεγραμμενον, βαρυτερον μεν, το εκ πλειονων* ΤΩΝ ΑΥΤΩΝ *συνεστος*. *Arist.* de Cœlo. Lib. 4. c. 2.

though, during the whole time of the operation, which lasts about an hour, the regulus sends up a thick smoke, and thereby loses a considerable part of its own proper substance.

There are, I think, but two possible ways of accounting for this effect. 1. If the quantity of matter be the same after calcination, or something less (the smoke being allowed for) than it was before, while the gravity of the whole is become greater, then the gravity does not follow the quantity, and consequently it is no *property* of the matter. 2. If there be an increase of the mass, it can be imputed to nothing but the matter of light or fire entangled in its passage through the substance, and so fixed in its pores, or combined with its solid parts, as to gravitate together with it. On this latter supposition, the matter or fire must have a density, which will introduce great confusion into the doctrine of a vacuum. But, to come still nearer to the purpose, it will also be said, that if this fire did not gravitate till it was fixed in the metal, (and it will be hard to prove that it did,) then we have a fluid which gravitates in some cases and not in others: so that the same conclusion offers itself, which way soever the experiment is interpreted. It will

be

be vain to suppose that any heterogeneous matter floating in the air, or that the air itself, is hurried into the mass by the action of the fire, and the weight increased by this means. For it is known experimentally, that, if a quantity of metal be even hermetically secured within a vessel of glass to keep off the air and all foreign matter, and the vessel be placed for some time in a strong fire, it will exhibit the same effect. I have seen the operation performed on two ounces of pewter-filings, hermetically sealed up in a Florence-flask, which in two hours gained 55 grains, that is, nearly $\frac{1}{17}$th*: had it remained longer in the fire, it might possibly have gained something more. The calx of lead, commonly known by the name of red-lead, is reckoned to gain one-tenth; at which rate, 10lb. of fire will be fixed in 100lb. of lead. If this trial were made in ten thousand different places of the world at once, and repeated an hundred times in a year, no reason can be given why it should not succeed. But the quantity

* In one experiment of Mr. Boyle on copper-filings, the increase by fire was $\frac{49}{480}$, that is, something better than one *tenth*. In another, an ounce of tin calcined gained a drachm, that is, $\frac{1}{8}$; and steel filings more than $\frac{1}{4}$th. See *his experiments to make fire and flame ponderable.*

tity of fire thus imbibed, allowing the proportion above mentioned, would amount to 10,000,000lb. which, according to the modern law of gravity, is more than ought to replenish the whole orbit of Saturn. Yet, I presume, the heavens and the earth would be as plentifully stored, to all intents and purposes, with this element as they were before: fires would burn, the sun would shine, and electrical experiments succeed in all places just as they do now.

As a sequel to what has here been observed concerning the impregnation of solid substances with the particles of fire, and particularly that of minium or red-lead, give me leave to subjoin an experiment of Mr. De Stair, which I borrow from the excellent Niewentyt. He tells us, that upon heating red-lead in a glass, (from whence the air was exhausted,) by the rays of the sun collected in a burning glass, the vessel, in which the said red lead was contained, burst in pieces with a great noise *. Now, as all explosions in general must be ascribed either to an admission of the air into a rarefied space, or to what is called a *generation* of it, and as it was not admitted upon this occasion, it must have

* Page 314.

have been generated from the calx within the vessel; and certainly was so, because Dr. Hales has made it appear, that this substance, like crude tartar and many others, will yield a considerable quantity of *air* in distillation *. What went into the metal therefore as *fire*, comes out of it again as *air*; which in a manner forces us upon a conclusion of inestimable value in natural philosophy, and such as may carry us very far into what Mr. Maclaurin has termed, with great judgment, the *most sublime part* of it. The ingenious experiments of Dr. Hales seem to have given him a sight of it, as I conjecture, from his having mentioned, on this occasion, the *aerial particles of fire* †. The force of all the fulminating powders, the violent ebullition of some mixtures, the sudden ascension of others, the inflammability of oils and other combustible matters, together with the taste, strength and fermentation of liquors, the operation of menstruums, &c. do all suggest the same thing; and might, with great appearance of reason, be deduced from one and the same principle, if this were a proper place for enlarging upon it.

 I had

* Veg. Stat. p. 287. † Ibid. p. 286.

I had a design of bringing in here another series of experiments, to shew that the gravity of bodies, where those bodies are of different kinds, is not in the direct ratio of their actual quantities of matter. But these are so very critical as to require perhaps a knowledge of the intimate constitution of bodies to judge of them properly: and my conclusion, supposing it to be true, would not be very obvious. It is therefore better wholly to omit them; for why should we lay a stress upon any thing not sufficiently clear and plain, when there is evidence ready at hand, the force of which may be apprehended by readers of all classes? It is wisely ordered by the Divine Providence, that what is most necessary to be known of nature, is generally the most easy to be understood: and if I assert that "gravity is no universal "quality of matter, because all matter does "not gravitate," I may have recourse to a phænomenon of equal extent with the creation itself; and which, without an hyperbole, is as clear as the sun at noon-day.

Gravity, it has been said*, is the "quality of all bodies on which any experi"ments have been made;" and that as bodies

* Princip. Lib. 3. Prop. 6. Cor. 2.

bodies near the earth gravitate toward the earth, so all "bodies in the heavens gra-"vitate toward the sun*." But if we believe this, there is an end of all experience: for, supposing this to be true, not one atom of light could ever come to us from the body of the sun. Who would undertake to prove, that the air of our atmosphere did gravitate toward the earth, if it were incessantly flying off from it toward the moon and the other planets? This is the case with the atmosphere of the sun. A flood of matter is sent off every moment with immense rapidity, from his orb, in a direction opposite to that of gravitating bodies; and in so large a quantity, that no space, however small, could be assumed within the whole solar system, where the point of a needle could be opposed to the sun, without stopping some thousands or millions of the particles thus sent from him. So long as the sun shines, a man must do violence to his own senses, if he can believe a centripetal tendency to be the quality of *all* matter; when the matter void of that quality, is in all appearance as far superior in quantity to the matter possessed of it, as the whole

* Princip. Lib. p. 469.

globe of the earth to an ordinary mountain. But be the quantity great or small, if the solar light is only allowed to be a material substance, the conclusion will hold good.

This grand objection to the gravitarian hypothesis has never been stated, or directly replied to, in the philosophical works of Sir Isaac Newton; and is generally passed over in silence by all his proselytes; though there is nothing more worthy of admiration, nor more beneficial to mankind, in the whole œconomy of created things, than the constant emission of light from the sun.

There are indeed two arguments, if they can be called such, by which our attention seems to be tacitly called off from this difficulty. They are certainly of no great importance in themselves; but by passing through the pen of Sir Isaac Newton, they are rendered too considerable to be neglected. The first is a position borrowed from Aristotle and Descartes, that "matter differs from "matter only in form, retaining all other "properties in common*." But this cannot be admitted without some proof; because it is the very point in question. That gravity is one of those properties which are retained

* Page 362.

retained in common, though the form of the matter be different, is an article which has never yet been proved, and I humbly think never will be; the propagation of light from the sun being a positive instance to the contrary. It would be weak to oppose an unsupported assertion, a mere logical subtilty, to so plain and important a matter of fact, the conclusion from which is so visible that nothing but art or prejudice can avoid it: it depends not on *words*, but on the visible constitution of *things*, and offers itself to the common observation of all men in the great outlines of nature.

Another method of evading this difficulty, is, to represent the element of fire, or matter of light, as a mere nothing; a substance which may occupy a space in so singular a manner as to leave it *empty* *: and it seems to be questioned, whether a reader will recollect that there is such a fluid as that of light in the solar system †. Where we might have hoped to receive from so masterly an hand some instruction concerning the nature and uses of this wonderful fluid, we are

 amused

* *Empty celestial spaces.* Opt. Q. 21.

† Si FORTE vapores longè tenuissimos, & trajecto LUCIS radios excipias. P. 328. Princ.

amused with a long account of transmutations, unnatural and romantic, founded on an experiment of Mr. Boyle, in which he thought he had obtained fixed earth from water. But Boerhaave * carefully examined this, and found it to be a mistake. Hence however Sir Isaac inferred, that as water is turned into earth, so gross bodies are turned into light, and light into bodies †: though, by a principle adopted on another occasion, all this is rendered very improbable, if not altogether impossible. He is of opinion, that the primitive particles of bodies will "compose bodies of one and the same na-"ture and texture in all ages ‡;" with which all transmutations whatsoever are inconsistent. In short, the matter of light seems to have been but a troublesome guest in the mathematic philosophy, though the author of it was indebted to it for the best and most durable part of his reputation. And long may it last! it is no interest of mine to wish

* See *Shaw's* edition of *Boerhaave's* Chemistry. vol. 1, p. 471.

† Mr. Boyle has an hydrostatical experiment to prove, that, when the weight of any metal is increased by fire, the fire is *not turned into metal*.

‡ Opt. p. 376.

wish that the fickleness and inconstancy of mankind may ever deprive him of it. He asks, "Is not fire a body heated so hot as "to emit light copiously? for what else is a "red-hot iron than fire *?" Let us answer this, by putting a like question concerning the element of water. "Is not water a body "wetted so much as to wet every thing else "copiously? for what else is a wet sponge "than water?" In this latter example every person will allow the sponge to be a distinct body from the water, containing that element in its vacuities. Now fire is as truly an object of sense as water; and hath as many properties to distinguish it as a fluid. What can a red-hot iron be, therefore, but *iron and fire* †, that is, iron with the element of fire in it? as boiling water is fire and water; and may be demonstrated to be such, by including it in an exhausted receiver, as well as by some other methods; though, I presume, the epithets *red hot* might accord better with the inclinations of Sir Isaac, than a noun substantive would have done.

All

* Q. 9.

† Μιξιν δ' ειναι ΔΥΟ η και πλειονων ΣΩΜΑΤΩΝ ως επι τȣ ΠΥΡΟΣ εχει και τȣ πεπυρακτωμενου ΣΙΔΗΡΟΥ. *Stob.* Ecl, Phys. lib. 1. c. 20.

All these things being considered, I beg leave to propose it as a *query* of some importance, whether Sir Isaac did not think it his interest to get rid of this powerful element, or at least to reduce it so low in the esteem of his readers, that it should never be able to do his system any harm? As for argument, there is little or none in the case: had there been any, his penetration would soon have seized upon it: therefore Boerhaave, Gravesande, Niewentyt, and others, embraced a contrary opinion; holding fire to be an element *sui generis*, and rejecting the whole doctrine above-mentioned, without bestowing upon it, to the best of my remembrance, any serious refutation; though they all concurred unanimously in admiring Sir Isaac as a most excellent geometrician. And indeed it is not worth disputing about: for, to say nothing of chemistry, the experiments of electricity, how great soever the prejudices of the learned may be at present, will in due time get the better of such unserviceable speculations. There have already been some laudable attempts in this way, though they are but few; and some of the gentlemen who have been engaged in this study, seem to be terribly affrighted at the conse-

quences of their own discoveries, treating the element of fire with as much caution as if they were touching it with their fingers. The ingenious Mr. Watson, whose experiments are very curious, inclines to the elementary side. Dr. Hill, after the examples of Boerhaave, Homberg, and the younger Lemery, does the same, in a learned work intitled—*Thoughts concerning God and Nature*. He has ventured to add some spirited reflections, in a way peculiar to himself, on the modern philosophy of fire; which, I suppose, the facts he is master of will sufficiently justify. What he has said in his 5th book, from the beginning of the 3d to the end of the 7th chapter, deserves well to be considered: his hints, though very brief, contain in them more truth, in my humble opinion, than any essay published on the subject since the cultivation of electricity in *England*. Others there are, again, equally respectable for their ingenuity and industry, who are very unwilling to admit the agency of an intelligible fluid, such as fire is. They will persuade us, it is improper to call the electrical fluid by that name; it being not fire, but the subtile æther so frequently spoken

spoken of by Sir Isaac Newton*. The negative part of their opinion they thus illustrate —— as air cannot properly be called sound, so neither can this fluid be called fire. Air, they say, raises the idea of sound, and this fluid causes a body to shine, or be on fire: but as air cannot be called sound, merely because it raises the idea of sound; so this fluid cannot be called fire, merely because it excites fire. Any reader who is possessed of a little logic, will immediately perceive this to be, not an argument, but a transposition of terms. For the parallel, in their way of drawing it, is really this:—as the air, that causes bodies to sound, is not sound, (it should have been, *is not air;*) so fire, the fluid that causes bodies to burn and shine, *is not fire:*—the inconclusiveness of which is sufficiently evident. Fire, with all its old properties, and some new ones, is the agent discoverable by sense in electrical experiments: this fluid, which *appears* in all the experiments, they over-look; and would solve them all by another fluid, which (like the *fifth element* of Aristotle,) never

* Observations on a series of electrical experiments. By Mr. Wilson and Dr. Hoadly, p. 69, 70.

never yet appeared, nor ever will in any one of them. Electricity may well be dark and difficult, if ingenious men refuse to be governed by their own eye-sight, because it would suggest, even to the meanest capacity, some principles differing from the most eminent geometrician of their own country; who, being but a man, was liable to error like other men: if not, I am greatly to be blamed for what I have written, and for concluding, as I take the liberty to do, without any fear or reserve, because I could prove it by numberless experiments, that fire is the most powerful agent in nature; that the whole heavens, as it is manifest to sense, are replenished with the substance of light; and, what is above all to be regarded, that it issues from the sun's orb in a direction contrary to that of gravity: that therefore, Sir Isaac Newton's universal law is false by experience.

The same may be concluded from another consideration of much weight, and almost as plain as the foregoing.

The materials of this terraqueous globe are generally agreed, both by the ancient and modern inquirers into nature, to have been once in a separate and disorderly state.

The

The sacred writings are known to have asserted this very expressly; and to have added withal an account of particulars, so far as it is needful for us to be acquainted with them. Between this account, and the heathen traditions relating to the same affair, there is a surprising agreement; of which so many examples have already been collected by Grotius *, and with so much learning and judgment, that very little needs to be added to what he has said. Taking it then as granted that the parts of this earth did once subsist as a formless and incoherent *chaos*, a question will naturally arise, by what physical means or agency, in subordination to the Divine Power, they were brought together, and put into the orderly form in which we now find them? Ovid says it was by a *melior natura;* which is a phrase without a meaning, and answers no end but that of filling up his verse. Descartes supposes the world to have *put itself* into order, by an imaginary motion of his *vortices*. And Sir Isaac Newton tells us, "the globe of the "earth and sea affects a round figure by "the mutual attraction of its parts by gra-"vity †."

To

* Grot. de Verit. L. 1. sect. 16. † Opt. p. 370.

To know whether this last supposition has any truth in it, we must have recoures to observation. If the parts whereof the several strata of the earth consist, and which appear to be no other than the sediments of water, did originally subside by the agency of gravity; the strata should lie in the order of their specific gravities; and the extraneous bodies buried in them should have the same specific gravity with the strata wherein they are found.

All this, Dr. Woodward assures us, is agreeable to fact. "This subsidence happened "generally, and as near as possibly could "be expected in so great a confusion, ac"cording to the laws of gravity; *that* mat"ter, body or bodies, which had the greatest "quantity or degree of gravity, subsiding "first in order and falling lowest; that "which had the next, or a still lesser de"gree of gravity, subsiding next after, and "so on *."—"the lighter shells fell amongst "the lighter matter, the heavier shells "amongst the heavier †;" and in a word, all the materials of this earth are generally so disposed as they ought to have been by the agency of gravity. All this is asserted with

* *Nat. Hist.* of the Earth, p. 75. † *Ibid.*

with the greatest confidence; and by a writer too, whom we must allow to have been well acquainted with the structure of the earth. But it is so contrary to observation, that every common labourer, who has assisted in the turning up of a stone-quarry, or the sinking of a coal-mine, must know it to be false.

The bowels of the earth have been purposely examined with this view, nearly to the depth of 200 feet; and the lowest stratum hath been found lighter than the uppermost that lay immediately under the turf. A description of the strata, found in a coal-pit in *Staffordshire*, was communicated to the Royal Society by Sir Hans Sloane, and the specific gravity of the several specimens having been examined by Mr. Hauksbee, he made the following report—that "the gravities of the several strata are in no manner of order, but purely casual, as if mixt by chance*." And as to fossile shells, bones of animals, mineral concretions, &c. they are deposited indifferently at all depths, and are to be met with in all kinds of matter. The *echinites*, a fossile body formed in a shell

* *Phil. Transact.* No. 336, p. 541. or Hauksbee's *Experiments*, p. 317.

shell of the crustaceous kind, which is very light, is found in chalk, in clay *, and in stone. Cockleshells and fossile-plants are found at the same depth; and, not to multiply instances, the *pyritæ*, a sort of metallic nodules, are generally found in *chalk*. I selected one of these bodies, of a spherical form, with some of its native chalk adhering to it; and found its specific gravity to be to that of common water, as 4. 59 to 1; nearly the same with that of some grey lead ore, which I compared with it at a venture, and found to be as 4. 83 to 1. How a body of this weight could be deposited amongst chalk by any law of gravity, is to me inconceivable; and Dr. Woodward's motive for so strangely misrepresenting this whole affair, would have been equally inconceivable, if he had written an hundred years ago; but at the time his thoughts were employed on the *natural history of the earth*, gravity was coming into vogue as a new *primum mobile;* and there are few men, who, for the sake of truth, will run the hazard of having their literary productions, the fruit of much labour and study, neglected or evil-spoken of as soon as they are published; though, in succeed-

* *Luid. Litolph.* Cl. 6. Art. 926.

succeeding times, when the heat of fashion is a little abated, they will be respected the more for it. If Dr. Woodward's aim was such as I imagine it to have been, he certainly failed of it in some degree. The introducing of gravity into his work might gain him many friends and some few proselytes; but it infused into others a very strong prejudice against him: for this appears to have been the principal reason which moved Mr. Ray to reject his hypothesis of an universal dissolution. He suspected it to be an invention subservient to the new principle of gravity; knowing that the phænomenon, which he would have solved by such a dissolution, was not generally true, and that we have sufficient authorities to prove the contrary *.

Though the nature of my subject hath obliged me here to make so free with Dr. Woodward in one article, I have no desire to lessen his real merit; which is that of having treated the subject of the universal deluge in a manner far superior to all writers who had undertaken it before him. But in the article relating to gravity, to say the best we can of him, he was mistaken.

Had

* Ray's Three Discourses, p. 167, 4th edit.

Had the earth been put together in the manner he has supposed, by the attraction of gravity, the natural order of things would have been inverted, and the economy of the world thrown into the utmost confusion. All the water of the globe would have been uppermost: all the gold and other metals would have subsided to the central parts. And although the poet has fixed a *stigma* on his *effodiuntur opes,* yet had they been carried down to the centre, how many hands had been unemployed, and left to idleness or mischief, for want of necessary labour. What should we have done for instruments of iron and brass; I will not say for warlike and destructive purposes, but for necessary and mechanical uses? To be short, the disposition of things below the surface of the earth is so ordered, that mankind may reap the greatest benefit from it. And does it not plainly demonstrate, at the same time, that though bodies may fall to the earth by what we call gravity, this gravity is but a partial phænomenon, and was never employed as a ruling principle in the conformation of this terraqueous globe? If to the facts here collected we add the density of elementary fire as found by experiment, and the perpe-

tual efflux of light from the sun, the result of the whole is—gravity does not prevail as an universal principle, either in the heaven above, or in the earth beneath; and consequently, a system of philosophy, which both supposes and requires it to be universal, hath mistaken the agency of nature, and is so far at least contradicted by experience.

CHAP. VI.

The Forces of Attraction and Projection, commonly called Central Forces, *will not consist with the Motion of the* Planets, *even upon the supposition of a* Celestial Vacuum.

I Have but one more observation to make in regard to gravity. I own it to be something in the nature of a digression, and as such I hope it will be excused. This principle then, compounded with a projectile force, will not account for the motion of the heavenly bodies, even allowing the spaces in which they move to be void of all resisting matter. We are under no obligation to grant this; however, let us grant it for

for argument's sake, and see what will follow.

A body acted upon by two different forces at the same time, will describe the diagonal of a parallelogram, whose sides are respectively equal to the two forces. Experiment shews this to be true; the *application* of it is what I am here to treat of; and I shall endeavour to be as short and as plain as I possibly can.

The celebrated author of the Principia, as it is universally known to all those who have but dipt into natural philosophy, supposes a planet to be acted upon by a projectile force giving it motion in a right line, which makes a tangent with its orbit. This force, once impressed, is always to continue by his *first law of nature* *. It is also acted upon at the same time by a centripetal force; which some observations upon the moon have induced him to believe is the same with

* Sir Isaac's first law of nature is this—*All bodies continue in their state of rest, or motion, uniformly in a right line, except so much as they are forced to change that state by forces impressed.*

Prima lex naturæ, quod unaquæque res quantum in se est, semper in eodem statu perseveret; sicque quod semel movetur, semper moveri pergat, nec unquam mutetur nisi a causis externis. *Vid.* Cartesii *Princip. Philos.* p. 2. sect. 37.

with what is called gravity near the earth's surface. By the former of these forces alone, it would always proceed in the tangent or right line; by the latter, it would fall straight to the centre; by both of them jointly, it will be gradually bent below the tangent, and in a given time, sufficiently small, will describe the diagonal of a parallelogram, whose sides are as the two forces. In a second moment of time, it will describe another, and so on. Now if these parallelograms are imagined to be infinitely small, a series of their diagonals will not sensibly differ from a curve: and thus he accounts for the motion of the planets in curvilinear orbits.

The greatest adversaries of Sir Isaac Newton must allow the thought to be highly ingenious. A thorough mathematician is so smitten with the elegance of it, and with the wonderful things he has deduced from it in a course of abstruse theorems, in which few are able to follow him but those who do it to a degree of enthusiasm, that they will very hardly be induced to quit their theories for a while, and condescend to examine how this speculation will consist with practice.

If I had an inclination to multiply words, I might object to the generation of a curve by the diagonals of small parallelograms; because there follows from it this absurdity, that as these diagonals can be considered only as right lines, no curve can be composed of them, unless a curve and a right line are commensurable, which every geometrician knows to be false. It would be idle to insist upon this, because the thing does assuredly hold good in nature, whether the *method of infinites* will consist with geometry, or not. A curve is evidently described by a projectile; and that projectile appears to be actuated by two forces thus compounded. As far as I am able to judge, there is no reason why the orbit of a planet, provided the forces are adequate to the effects, may not be produced in the same manner. But I humbly think, the forces of *gravity* and *projection*, which were proposed long ago with this view by Mr. Horrox *, are inadequate and unfit for the business

* Testantur observationes—figuram orbitæ planetariæ esse ellipticam—motumque ejus in hoc elliptico inæqualem esse, & pro distantia ſua a ſole intendi & remitti—*Projiciatur* plumbum aliquod in altum, surgit *primò velociter, deindè tardius*, dum tandem stationarium in terram recidat *continuo*

siness assigned them. No *lasting* motion, as it will soon appear, can possibly arise from a composition of *these* two forces, for the following reasons:

Let us imagine the two forces to be represented by two bodies, A and B, (see *plate* II. fig. 1.) and let these be made to strike against a third body, C, at rest. Now, it is certain, from the laws of percussion in bodies not elastic, 1. that if A and B are carried with equal quantities of motion toward contrary sides, and do both impinge at the same time against C, no motion is produced by it, but all the three bodies remain perfectly at rest after the stroke. This may be laid down as the most simple case. 2. If the angle of their meeting at C be very obtuse, as A C B (fig. 2.) the motion communicated to the body C will be equal to the diagonal C D; so that the whole *sum* of the force hereby produced,

continuo velocitatis incremento, atque ita motum librationis describit—oritur ea libratio, ex *pugnâ virtutis illius* quam manus tua illi infudit, unà cum *virtute telluris* magneticâ, quâ omnia *gravia* ad se *attrabit*.—Quid est quod *in motu planetarum*, ubi eadem commoditas non deest, *causam veram* a naturâ ipsâ tot exemplis confirmatam, fictitio circulorum somnio commutaremus? *Horroc*. Op. Post. p. 181. § S.—This wonderful adept in astronomy flourished towards the beginning of the last century, and died at the age of 22.

PLATE II. to face P. 168, Vol. 8.

Fig. 1.

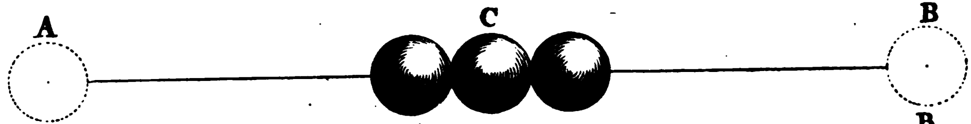
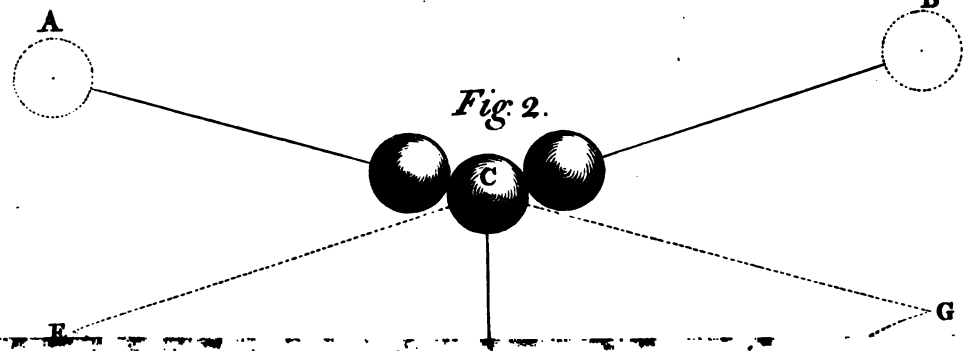


Fig. 2.



duced, is not equal to either of the forces *singly* which produce it, and all the remaining part is lost. In the first case, the resistance between the two forces was total, here it is but partial. 3. If the angle of meeting be less obtuse, right, or acute, as in the 3d figure, the motion produced may be equal to *one* of the forces, as C D, where the angle L C M is 120 degrees (the triangles on each side the diagonal being *equilateral*) or greater as C G, but can never be equal to *both*, till they coincide in the same right line: which case is the reverse of the first; for, by such coincidence, the communication becomes total, and the resistance vanishes.

I shall be sorry if the word *resistance* gives any offence to those who have been accustomed to a different way of reasoning; but if they can, upon the received principles, distinguish between *resistance* and a *loss of motion*, I confess it is more than I am able to do. Motion, they must allow, is always lost in the *composition of forces*. There is an easy way of shewing this experimentally, by three weights pulling at the same centre with oblique forces. Thus, if the weight A (fig. 4.) of 3 pounds, and the weight B of 4 pounds, pull against each other at an angle

of

of 90 degrees, they will counterpoise a third weight, as c, which is only 5 pounds. The difference, or loss, is equal to 2 pounds: but how can this be, unless the compounded forces 3 and 4 do in some manner counteract each other? and what can we call this but *resistance?* The thing will be just the same, whether the word be admitted or not: a motion thus produced, by a *composition of forces*, cannot be lasting, unless these forces are perpetually *renewed.*

The application of all this is easy enough. The centripetal force upon a planet, having a constant supply, will be increasing every moment, and bring the planet nearer to the centre. But the projectile force originally impressed, having no recruit but from the *first law of nature*, which is none at all, must vanish by degrees; and it makes no difference in the argument, whether you suppose it to vanish in ten years, or in ten thousand. Hence, it is impossible for a body actuated by *these* forces, to describe a curve which shall return into itself. A mathematician may make this appear plausible upon paper; but it is no practical truth, be the speculation ever so pleasing.

It is necessary then to call in the assistance

of

of some medium, as an agent, to renew this projectile force as fast as it decays. Philosophers might perhaps find their labour well repaid, if they would inquire whether any such is to be met with: and they will pardon me, if I tell them, such an inquiry can be no disgrace to them; for *Galilæo* himself, the greatest geometrician of his time, to whom the present age is indebted for a considerable part of its knowledge, was persuaded the sun might occasion the motion of the planets in a mechanical way *.

It should also be considered, now we are upon this subject, that the motion of the planets is not perfectly circular, but *elliptical*. At some times they are driven farther off from the sun toward the higher *apsis* of their orbits; at other times they approach nearer to him, as they tend toward the lower. To this it is wholly owing, that the earth is nearly eight days longer in passing from the vernal equinox to the autumnal, than from the autumnal to the vernal. If they are carried off by a projectile force, and brought nearer by an attractive, neither the one nor the other can continue in the same state through any one of their revolutions, or, to speak

* See his Letter to the Grand Duchess of Tuscany, p. 57.

speak more strictly, through any two points in one half of their ellipses. How are we to account for it, that the projectile force, when once overbalanced by the attractive, does not so far decay, as to let the planet draw up in a *spiral* till it falls into the centre? When the attraction of gravity is accelerating the motion of a planet or comet, and causing it to approach nearer to the sun with great rapidity, it brings it down to a certain point only, but never below it: for when it has reached this point, it rises again immediately, which, without supposing some *new force* to act upon it, is altogether impossible. In the theory of projectiles in *vacuo*, there is no case parallel to this, or in any degree like to it: for, let a planet be projected from the higher apsis of its orbit, with any force less than infinite, and its descents below the tangent, according to the known laws of projection, will be as the *squares of the times* from the beginning of its fall, till it attains a point either of relative or absolute rest.

As to the motion of the moon in particular, there are, upon this same plan of gravity and projection, some certain circumstances attending every conjunction, which are known to contradict the first principles of

of mechanics; but these, if insisted upon at large, would carry me out far beyond my design. An author I have already spoken of, who, if I comprehend him, is a most zealous assertor of gravity and a vacuum, has, to my great surprise, represented this and some other things which have frequently engaged my attention, in a method so plain and unanswerable, as to render my labours unnecessary. To his book, therefore, I beg leave to refer those who require any farther satisfaction *. In our *conclusions*, I must confess, we differ very widely. The end I have proposed in mentioning these things, is to shew the necessity of a material agency in the heavens, subordinate to the Divine Power: whereas, it is his design to shew, from the same premises, that God himself is the agent immediately. Which of these two is the more rational inference, I leave to be determined by the impartial judgment of others, after they have weighed the following reflection:—That if the extravagances, which would arise in the planetary motions from attraction and projection, are any way to be corrected and regulated, it must

* See *Appendix* to an Inquiry into the Nature of the Human Soul, sect. 8.

must be done either *physically*, by the instrumentality of some material agent properly adapted, or *supernaturally*, by some immediate influence of Divine Power: if *physically*, then the motions which are *corrected* by a physical agent, may as well be *caused* in the same manner; if *supernaturally*, that will give every pretender to philosophy a liberty of proposing what powers he pleases, and all of them equally good, if they are to be mended at every turn by a miracle. Indeed, it will be no better than a jest to propose any powers at all; and Sir Isaac's first *law*, which is called a law of *nature*, and from which he hath attempted to deduce so many things in a *natural* way, will have neither meaning nor use in philosophy, if this author's doctrine be admitted. A miraculous interposition, therefore, is never to be confounded with the established order of natural things, if we would understand what nature is, or what a miracle is. Such a method of philosophizing will give a sanction to every ridiculous hypothesis, that doth not quite come up to an impossibility; and I can see no good reason, why the *vortices* of Descartes may not claim the benefit of a miracle to supply their defects, as well as this more mo-

dern, but equally fictitious, composition of *central forces*. Upon what principle was it that Sir Isaac Newton said—"*Hypothesis* "*vorticum multis premitur difficultatibus?*" certainly not upon the principle of this author; for, at that rate, there can be no such thing as a *difficulty*. The same omnipotent hand, which is supposed to save a planet from ruin, by driving it farther from, or drawing it nearer to the centre, as occasion requires, may as easily conduct a comet through the whirling *vortices* of Descartes, or even the solid chrystalline orbs of Aristotle. This is the common refuge of men who have nothing else to say; and it was the excuse advanced by Ptolemy, in behalf of his perplexed scheme of *eccentrics* and *epicycles*. No man was to call in question the truth of his astronomical theories, because the *immortal gods* could easily find a remedy for every difficulty; could remove all impediments, and make a way in the heavens for the motion of every orb, though their courses might seem to be inconsistent with one another *. When the philosopher assures us *power* is a divine attribute, we can readily believe him; but if

* Nemo vero difficiles censeat has quas supponimus circulorum implicationes, &c. *Kepler.* Epit. Astron. p. 502.

if he is above searching after what the divine *wisdom* hath thought proper to establish in the world, and takes refuge under the abstract notion of an unlimited power, before there is a necessity for it, and even while experience is against him, he betrays the insufficiency of his own speculations; and must convince mankind, either that the whole of nature is an useless and inexplicable mystery, or that he ought to set out afresh upon more consistent principles.

END OF THE SECOND BOOK.

BOOK III.

Of a Vacuum *in the Heavens, and between the Parts of Bodies: with an experimental Inquiry into the physical Causes of* Cohesion *and* Repulsion.

CHAP. I.

Some positive Proofs that a Medium, *different from the Rays of Light, is present in the Heavens; with an Answer to a common Objection, from some Experiments with the* Barometer.

THE best-reputed argument hitherto made use of to prove a vacuum, has been derived from a supposed *necessity* for it, that the bodies in the heavens may be *unresisted* in their motions. But we have been taught by some undeniable examples, that motion may continue unresisted in a resisting

 medium,

medium, if that medium be the *cause* of the motion: so that the whole doctrine of resistance is of no use, unless the question be first granted, that the motion of the planets is not owing to any *material cause;* that is, unless the very thing, which ought to be proved, be taken for granted. If the matter of the heavens is not employed as a physical cause, then, indeed, it will be an obstruction, and serve only to interrupt and retard motion. If the air *behind* the sails of a ship were not instrumental in driving the ship forward, the air *before* the sails would serve only to stop the course of it. If a motion were communicated by the hand to the lamp-machine described in the former part of this treatise*, and it were made to turn upon its centre when the lights are extinct, the air which surrounds the vanes would resist their progress, and the machine would not make near so many revolutions as if it had been included in a vacuum. But if the lights are burning, the case will be entirely altered, and the air will now conserve that motion, which a while ago it destroyed. This distinction of cases is ever to be remembered in all our physical reasonings: the

* See page 68.

the most ingenious and able philosophers, by not attending to it, have fallen into palpable mistakes; and it is greatly to be lamented, that the fact here mentioned has found no place in the received philosophy, though it calls itself *experimental:* nay, the impossibility of such a thing has been formally demonstrated in a geometrical way.

A vacuum, therefore, is no *necessary* principle. We should rather conclude, if we are willing to be guided by analogy and experience, that, as motion continues in the heavens, some active medium must be present for the conservation of it. Let us inquire, then, whether the existence of such a medium in the heavens, exclusive of the rays of light, will admit of any positive proof; and whether we can obviate a material objection which hath been raised against it: after which we will leave the celestial vacuum, and examine the nature of some lesser vacuums.

So long as the philosophy of Aristotle prevailed, *positive levity*, differing only in specie from gravity, was believed to be a quality of some natural bodies: but the members of the Florentine academy shewed the falsehood of it by some judicious experi-

 ments;

ments; and it is now determined, that if one body or fluid *tends upwards*, it is only because another of greater density *tends downward*, and takes the place of it. Thus, if air and water be mixed together, both of them gravitate (as we commonly speak) toward the centre of the earth; but the water, having the greater density, will gain the lowest place, and, in so doing, cause the air to *ascend* with a velocity proportional to their difference. What is here said of air and water, may be applied to smoke and air, the cases being alike in all respects. This reasoning, if found to be just in every instance where we have an opportunity of making the trial, must be admitted on all other occasions of the same nature, though we have not the like opportunity: according to to the known rule—*Effectuum naturalium ejusdem generis eædem sunt causæ*—" Natu-" ral effects of the same kind must be im-" puted to the same causes." If this liberty of arguing from a similarity of effects be once denied us, all *experimental* philosophy will be in a manner useless.

I must be permitted, then, in virtue of this rule, to argue from the ascent of bodies near the earth's surface, to the like effect

when it happens at any distance from us in the heavens; as for example, near the head of a comet, from which an immense train of vapour is observed to fly off, or rather to *rise upwards* into the regions opposite to the sun; for thus we should express ourselves, if we were placed upon the surface of it.

Now let the observation concerning smoke and air be here applied; and it will be more than probable, that some fluid in the heavens, of a density much greater than these vapours, must be tending *downwards* to the sun, that they may be carried off in a contrary direction, according to the law above mentioned. For the same reason, this fluid ought to be present in all the spaces, through which the tail of a comet is known to extend itself, which is sometimes to an almost incredible distance; otherwise the principle of a positive levity, or something equally unaccountable, must be admitted as a consequence. An imaginary atmosphere, surrounding the nucleus of the comet, will give us but little aid; the case not being paralleled (I mean with respect to the comet and its own atmosphere) by any thing that happens within the atmosphere of this earth; in which smoke and vapour will rise up on every side indif-

ferently, as well at noonday as at midnight, and will go either toward the sun, or from it. But the tail of a comet, *after* it has passed its perihelion, as well as *before*, is turned away *from* the sun; at which time, as we should naturally expect, some more loose and detached particles might be left behind by the resistance of some ætherial medium, and carried toward the sun by their gravity: the contrary to which hath always been observed to happen: so that we must impute the whole effect to an universally extended atmosphere, not of the *comet itself*, but of the *sun*.

This phænomenon, though very distant and inaccessible, is nevertheless so clear in itself, and its application is so obvious, that it cannot easily be misunderstood. Those who believe the heavens to be nothing but an immense vacuum, are bound in reason, I think, to give us such an account of it, as shall be satisfactory in itself, and consistent with their own principle. If no such account can be given, there will be a necessity for introducing some fluid into the heavens beside the rays of light; and when we speak of such a thing, we shall do it with reason, with observation, and, I may add, with

with Sir Isaac Newton also on our side, who seems to have considered this matter attentively, and has granted all we can desire of him. His words are these—"For, as "in our *air* the smoke of any body that is "set on fire goes upwards, and that per"pendicularly if the body be at rest, or ob"liquely if it be moved sideway: *so in the* "*heavens*, where bodies gravitate toward "the sun, smoke and vapours ought to as"cend from the sun, and go off to the "higher regions *." This whole passage being very important, I must beg leave to subjoin a few short remarks upon the several portions of it.

"For, as in our air the smoke of any body "that is set on fire goes upwards," &c. The reason already assigned for this need not be repeated. Should it be disputed, experiment will make it good. For, let any burning matter be placed under a pneumatic receiver, not exhausted of its air; the smoke will rise up perpendicularly, and with a considerable velocity; but when the air is exhausted,

 the

* Etenim, ut in aëre nostro, fumus corporis cujusvis petit superiora, idque perpendiculariter si corpus quiescat, vel obliquè si corpus moveatur in latus: ita in cœlis, ubi corpora gravitant in solem, fumi & vapores ascendere debent a sole, & superiora vel recta petere. *Princip.* p. 469.

the smoke, instead of rising up as before, will either sink down like water, or hover as an atmosphere about the ignited body. It follows from this experiment, and many others, that a fluid which is light and rare, cannot ascend by any innate quality of its own; but must be impelled, or forced up, by another fluid more dense and weighty.

This ascent of smoke, &c. will be "perpendicular if the body be at rest, or oblique if it be moved sideway." Thus the flame of a candle will have a perpendicular direction if it is at rest; but if it is carried forward, and meets with a resistance from the air, the flame will then have an oblique direction, and be more bright and better defined at the edge where the resistance is made, than at the other. Astronomers tell us, the like has been observed in the tail of a comet. But we are coming now to the application.

"So in the heavens, where bodies gravitate toward the sun, smoke and vapours ought to ascend from the sun." As on the earth, to which bodies gravitate, smoke ascends through air, because the air forces it up by gravitating *more* than the smoke; so in the heavens, which, according to this same author, are *empty* of *air* and of all

sensible

sensible matter, vapours ought to ascend from the sun. How can these things stand together? Would it not be better totally to disbelieve a *vacuum* in the heavens, than to be thus distressed with contradictions? Sir Isaac himself, upon this occasion at least, seems to have thought so; therefore he adds again very expressly in another place— "Smoke ascends in a chimney by the im-"pulse of the air in which it floats. This "air, being rarefied by heat, rises up, be-"cause its specific gravity is diminished, "and carries off the smoke entangled with "it. Why may not the tail of a comet as-"cend from the sun after the same man-"ner*?" There can be no objection to this, but that the heavens will not then be *empty*. Vapours cannot ascend from the sun *after the same manner* as smoke rises in a chimney, if in the spaces through which they ascend, there be neither *impulse* nor *air*, nor any *sensible matter*.

If we agree here with Sir Isaac Newton, and

* Ascendit fumus in camino impulsu aëris cui innatat. Aër ille, per calorem rarefactus, ascendit ob diminutam suam specificam gravitatem, & fumum implicatum rapit secum. Quidni cauda cometæ ad eundem modum ascenderit a sole? *Princip.* p. 472.

and determine these cases to be a parallel, the conclusion will be unexceptionable; that as the *air*, in which smoke ascends, is no *vacuum;* so neither are the spaces through which vapours ascend from a comet.

And to go a step farther, the reasoning which hath been applied to these vapours, may be applied with the same propriety to the *rays of the sun;* for as the motion of both is in the same direction, no difference between them, in any other respect, will be material. Light then must be propagated from the sun, either by an innate *levity*, in a manner not analogous to any thing we are acquainted with; to suppose which is to give up the whole cause; or by the pressure of some denser medium going downward to the sun. It is true, Sir Isaac, in his Treatise on Optics, hath rejected all such mediums in a peremptory strain: but if his theory of resistance hath failed, we may be able to surmount all lesser difficulties. Indeed I know but of one that deserves to be considered. Upon a first view of it, it threatens us with some trouble, and will put us upon an exact inquiry.

It hath been judged, from some experiments with the barometer, that we are now

able to calculate the height of the air which surrounds this globe, and to fix very nearly upon that distance, beyond which, if there is any matter at all, it must be *perexigua* "exceedingly little," *aura longè tenuissima*, "an air thin beyond expression." The "weight of the atmosphere at a middle state, "is equal to 29½ inches of mercury, at the surface of the sea. If we ascend to the height of 800 feet, it will sink an inch lower; at double that height, it will be lower still; and so on, as far as we can convey ourselves to make the trial. Hence it is presumed there is a certain distance above the earth's surface, at which the mercury in the barometer would fall to a level with its cistern; and consequently the heavens, at that distance, must be empty of air, at least of such air as is attended with any sensible pressure upon the surface of bodies.

From all that has hitherto been done upon this subject, it does not appear that a theory can be laid down, so as to determine the stations of the barometer with accuracy, when the elevations above the surface of the earth are very great. When they are but moderate, this method of measuring altitudes is very convenient, and comes nearer

to

to the truth than a quadrant and a trigonometrical operation would do. But, I apprehend, the higher we go, the greater will be the error. Between Drs. Halley and Scheuchzer there is a difference of near 800 feet in 5000. The former of these having erected a theory *, finds an elevation of 5000 feet requisite to reduce the barometer to 24. 93 inches; while the latter, who pursued his inquiries with great diligence, and every imaginable advantage, upon the *Alps of Switzerland*, reduces the barometer to the same station, with an elevation of 4241 English feet †. There are other calculations of Mariotte and Cassini, which differ widely from each other.

But to come to the point. That there really is any imaginable elevation above the surface of the earth, at which the barometer would have no altitude, and the air no perceptible density, cannot be inferred from any barometrical experiments; all of them having been taken in that *lower region*, within which the air is no other than a menstruum, saturated to an high degree with hetero-

* For a particular account of it, see Philos. Trans. No. 181. p. 104.

† See *Ibid.* No. 406. p. 577.

heterogeneous particles of a grosser substance, and more especially with the particles of *water*. The clouds indeed, at least in this country, are very rarely higher than three quarters of a mile, even in the most serene weather, when the barometer is high; and sometimes they do not exceed seven or eight hundred yards, as I have found by observing their altitude at different seasons: but we shall err greatly if we imagine the watery vapours to be carried no higher than to the path of these clouds; for mountains, above a mile in height, being covered with *snow*, must be within the region of vapours. When Mr. Ray, as he tells us himself, was crossing the highest ridge of the Alps in the country of the Grisons, it *snowed* very fast during his whole passage, and "the clouds "seemed to be as far above his head as they "do here in England *." At the top of the Pico Teneriffe, as Dr. Spratt has delivered the account in his admirable *History of the Royal Society*, "a person found himself all "wet, and perceived it to come from a per-"petual trickling of water from the rocks "above him." Another account in the *Philosophical Transactions*, speaks of a *dew* fall-ing

* Three Discourses, p. 104.

ing there, at the very summit, so copious as to wet the clothes of the company; and it lasted till sun rising *. Varenius supposes, after all the proper deductions for refraction, &c. that the top of this mountain is visible at the distance of two degrees and an half upon the meridian; whence the height of it will be three English miles and three quarters. Whether this calculation be exactly right or not, though I think the real height cannot be very far short of it, certain it is, as Varenius hath observed, *quòd non ùltrà mediam regionem aëris protendatur* †—"that "it is not extended beyond the middle re-"gion of the air." How much higher the watery vapours may ascend, it will be hard to say; but so high they certainly do ascend.

From a very common experiment with the air-pump, water appears to be at all times suspended in the element of air. After a stroke or two of the pump, the remaining air within a receiver, being rendered lighter, never fails to let fall a cloud of vapours. Dry salt of tartar inclosed in a glass well stopt, will imbibe so much water as to make up

* N. 345. p. 317.

† Geograph. lib. 1. cap. 9 & 10.

up the largest part of the weight of the included air: which led Dr. Boerhaave to conjecture, that pure air, in its elastic state, does not gravitate at all*. I have sometimes admitted air into an exhausted vessel, fitted for the purpose, first in a dry room with a fire in it, then upon a damp staircase, and have found the latter to be something heavier, by hanging the vessel to the arm of a balance.

All these facts should be taken into the account, and some allowance be made for them in our modern atmospherical theories. They will not prove perhaps that pure air is absolutely without gravity, which is what I cannot believe; but they will prove very well what I intended to shew, that experiments made within the lower regions of the air, are by no means conclusive when applied to the higher, into which no barometer will ever be transported, unless Dr. Wilkins's scheme for flying up to the moon shall hereafter be put in execution.

To this admixture of vapours might possibly be owing those unexpected irregularities in the barrometer, which almost threw the

* See his *method of chemistry* by Dr. Shaw, vol. I. p. 400 and 419.

the industrious Scheuchzer into despair. During his peregrination upon the Alps, the mercurial column was sometimes *higher* upon those mountains, than it was observed to stand on the same day, and with the same temperature, at Zurich; which is directly opposite to the received rule*. He imputes this to the greater *purity* and *elasticity* of the air in the *Alpine regions*. These irregularities, however, drew from him the following confession, for which he is much to be honoured—"I pretend not to lay down the truth, "as if it were fully cleared of every doubt; "for, after all my inquiries, it seems to be "still concealed under a cloud†:" and indeed so it is; if, by *the truth*, we understand that theory of the atmosphere, which terminates in a *vacuum*.

But, after all, one positivepro of with regard to the higher regions, would be worth all that can be said in answer to experiments, on account of their not having been actually taken within them. Such a proof is to be met

* *Itinera Alpina*, p. 15. Itin. secund.—"*In diversorio Ragaziensi, &c.*"

† Imo nec prætendo veritatem omnibus dubiis plenè liberatam adhuc dum sistere, quæ operta nubium involucris mihi ipsi videtur. *Ibid.* p. 9.

met with, so plain and striking, that I may venture to rest this whole affair upon the strength of it.

According to the present state of experimental philosophy, air is allowed to be the vehicle of sound: and whether it be the proper pabulum of fire or not, it is, generally speaking, necessary to the kindling of fire, and to the preservation of it. When the receiver of an air-pump is well exhausted, a small bell cannot be heard to transmit any of its sound, if it be prevented, (as it easily may,) from communicating its tremors to the external air, through the solid matter of the machine. Gunpowder will not take fire in such a space; and a candle will expire before half the air can be extracted. These things being premised, I proceed to my narrative.

In the year 1719, a *meteor*, very far exceeding the moon in lustre, and nearly as large in appearance, was seen over all the parts of Great Britain, Ireland, and Holland, the nearer parts of Germany, France, and Spain, at one and the same instant of time. Its apparent altitudes were accidentally observed by skilful persons at

London, Oxford, and Worcester, and near enough to the truth, by the assistance of the stars. The horizontal distances of these places being known, together with the semidiameter of the earth, and the different angles under which the phænomenon appeared to distant spectators at the same time, its absolute height above the earth's surface may thence be found to a degree of certainty, which will not be disputed by those who are acquainted with the rules of trigonometry. From these data, it appears to have been about 70 statute miles high. Over Devonshire, Cornwall, and the neghbouring counties, an *explosion* was heard, equal to a report from a broadside of the heaviest cannon at some distance, which was soon followed by a rattling noise, as if many small arms had been promiscuously discharged. This sound was attended with an uncommon tremor of the air, and every where in those counties very sensibly shook the glass windows and doors of the houses, and even the houses themselves, beyond the usual effects of cannon when fired near at hand.

The account of this meteor was drawn up at large by Dr. Halley, from the intelligence received

received upon the occasion by the *Royal Society* *. The conclusion from the whole is plain enough: therefore, instead of making any remarks of my own upon it, I shall add the more weighty and ingenuous reflection of the celebrated author himself—"what "may be said to the propagation of sound "through a medium, according to the re- "ceived theory of the air, above 300,000 "times rarer than what we breathe, and next "to a vacuum, *I must confess, I know* "*not.*"

CHAP. II.

Some positive Proofs, that a Medium, *endued with* very great Force, *is present between the* Interstices *of grosser Bodies, and in other Spaces usually called* Vacuums.

LEAVING then the celestial vacuum to be proved by some future arguments, more unexceptionable than any hitherto advanced;

* *Phil. Transact.* No. 360, p. 978. This account is preceded by several others, leading to the same conclusion, in the 2d vol. of Mr. Motte's continuation of Lowthorp's abridgment, p. 138.

vanced; we must descend to examine the state of some lesser vacuums; whether made by the help of art and machinery, or left by nature itself in the interstitial vacuities of solid or fluid bodies. That none of these can, with any philosophical strictness, be termed *vacuums*, though we are sometimes obliged, for the sake of distinction, to call them such in common discourse, will be clear from the following considerations.

Suppose a receiver (plate III. fig. 1.) to be placed upon an air-pump, and well evacuated. Into the plate at the top of it, a cylinder of wood or metal is inserted, and made to communicate with an electrical machine in motion. If the room be dark, a stream of fire will be seen to issue from the lower end of the electrised cylinder, and go straight down to the plate at the bottom. But if any person applies his finger to the side of the glass, as in fig. 11. the stream will receive a new direction, and be bent to that part of the glass to which the finger is applied. The better the receiver is cleared of its air, the better this effect will be found to answer.

In the opinion of some spectators, prepossessed with the notion of *qualities*, this might

PLATE III, to face P.196, Vol. 8.

might pass for a good proof, that the finger *attracts* the fire. Nevertheless, that some subtile medium, though invisible, is present to divert the course of the fire, may thus be proved. It may be previously learnt from some other experiments, that the electrical fluid is acted upon according to mechanical laws. Thus, for example, the resistance of the air being much greater upon the spherical surface of a large cannon bullet, than upon the point of an iron rod; the fire will be confined within the bullet, while it escapes with ease from the point of the rod. Where the resistance of the air is removed from one part of a body while it acts upon another, the electrical stream will go off at that part from which the resistance is removed, without any regard to the figure of the body. In short, it is found, from these plain and intelligible cases, that this fluid *acts* as it happens to be *acted upon*, and is *impelled* to that side where it meets with the least degree of pressure. As the medium within the pores of solid bodies is known to resist it less than any other we are acquainted with, for this reason it is driven toward the finger. But then if there be no medium within the glass, the stream will be equally affected on

every side; or, which is the same thing, not pressed at all on any side, and ought to go directly down to the plate, as before in fig. 1; for an absolute vacuum, which is *nothing*, cannot be able to impel and divert the course of it. If it is *drawn* to the finger by an unmechanical attractive quality; then I am to conclude, against all reason, that this fluid is unlike to itself; mechanical on some occasions, and unmechanical on others. But we are under no necessity of falling into such a contradiction. An agent capable of acting upon it by a mechanical impulse or pressure, is present within the receiver; and if the reader is not convinced of this, by what I have already said, (as I can hardly expect he will, if these things are new to him,) what I am going to add will give some farther satisfaction.

If the electrical æther be *elastic*, as it is generally imagined to be, how can it pass in an uninterrupted column, through an exhausted receiver, as it does in fig. 1? A column of air, moved swiftly through the orifice of a small pipe, will go forward a considerable way, if it moves through other air, which is a counterbalance to it on every side: but if such a column of air enters a vacuum,

what

what we call its *elasticity* occasions it to be dissipated in a moment, and *equably diffused* throughout the whole exhausted space. As the like does not happen to the electric fire, it is either not elastic, which cannot be supposed, or the stream is counterbalanced on every side by a medium of its own kind, which prevents its dissipation. When it enters a medium rarer (that is, of more subtile parts) than itself, as within the pores of close and dense bodies, it is then equably diffused, like the column of air when it enters the exhausted receiver. When it meets with a medium denser than itself, as within the more open pores of glass, amber, rosin, &c. it will not enter without some violence, as air is with difficulty forced into and confined under water. From these few and obvious principles, naturally suggested by a similarity of circumstances in the air, a fluid more intelligible than the subtile æther, with which we have had but a short acquaintance, the most difficult appearances in electricity may be accounted for.

The presence of a medium, within an exhausted receiver, doth also follow; because there is no space, how perfectly soever it may be evacuated of common air, wherein

fire will not rise perpendicularly upwards from a red-hot iron, and heat a receiver at the top more than at the sides, though they are nearest to the fire. The fumes of gun-powder will be carried up together with the fire, and in the dark will exhibit a beautiful appearance, very much resembling that of an *aurora borealis.* I made this experiment with the mercurial gauge at 29 inches; and it would succeed, as we have no reason to doubt, could it be brought to the full height of a good barometer. From this forcible ascent of the fire and fumes, there must be other matter in what we call the *empty* space, by the *pressure* of which the fire is driven upward. Thus we argue in all parallel cases; and if this be excepted, we must have recourse to an *innate levity,* which has long been exploded, and justly enough *. Dr. Halley, indeed, does allow of a *tendency contrary to gravity,* and an *innate levity;* but I apprehend we are to take these for nothing more than unwary expressions.

The space at the top of a barometrical tube, if the mercury be pure, and the glass clean and dry, is a much better vacuum than that of a pneumatic receiver. But the more effectually

* See page 179, &c.

effectually it is cleared of air, the better opportunity we have of shewing it to be filled with other matter. For let the tube be inclined a little from the perpendicular, till the mercury reaches to the crown of it, then if it be suddenly restored to its first position, and the room be well darkened, or the experiment performed in the night, a pale light will be seen to occupy the space, as fast as it is deserted by the mercury; and this light will return, as it were by flashes, so long as the mercury continues to vibrate in the tube.

It was the fashion, some years ago, to give this barometrical light the name of a *mercurial phosphorus*, as if it were an anomalous production from the mercury; whereas this light, and the electrical æther, as some farther inquiries have taught us, are one and the same fluid; and the mercury is not necessary to the effect. If the glass of the tube be very thin, let the top of it be made to touch the *conductor* of an electrical machine, and the light will give the same appearance as if the tube had been agitated. After this, empty the tube of its mercury, and add some contrivance for exhausting it by the air-pump; then let it be applied to the

the conductor as before, and still you will have the same appearance of light.

When a bason of mercury is agitated *in vacuo*, large flashes of light will seem to be reflected from the surface of it. The mercury does not *create* this light, but only *renders visible* a fluid already present in the exhausted space. For the matter of light may, and actually does, exist, where the sense of seeing will give us no information of it. A piece of solid *phosphorus*, immersed in a phial of water, is in all appearance as cold and opaque as a lump of hard wax; but, as soon as it is taken out and exposed to the air, it smokes and shines, and, if excited by a smart friction, will instantly break out into an actual flame. This substance seems to be a mere creature of the fire, like fixed alcaline salts, and many other productions of chemistry; and in its preparation absorbs a large portion of that element into its pores, whence Lemery, with great propriety, calls it a *fire-sponge*. So long as it remains under water, the imprisoned fire is kept in a quiescent and invisible state; but if that pressure be removed, it breaks out in a stream, flying off as fire does from any other sort of fuel. It

escapes

escapes more easily under an exhausted receiver, than under the pressure of the atmosphere; for the same reason that a vessel of hot water will grow cold, and part with its fire much sooner under the like circumstances; and the electrical fire, instead of being charged, will return back its fire as fast as it is infused.

But the nature of that subtile medium, which remains in every space from which the grosser air is exhausted, may be farther understood, by inquiring into the force and condition of it within the *intersticial vacuities* of fluid or solid bodies. And as I shall take the liberty to speak of electric and elementary fire, as if both were but one and the same thing, I must interrupt a little the order of my discourse, by inserting my reasons for so doing; because some ingenious men suspect them to be different, and have attempted to render it probable by experiment, though their reasoning is not so strict as to deserve any particular examination.

1. We call that *elementary* fire, which lights a candle, kindles spirits, and fires gunpowder. The electrical *æther* will do all these; and if it be different from elementary fire,

fire, then we have *two* material causes in nature, intended to produce the same effects, when either of these alone would have been sufficient. And again; 2dly, if the electrical fire will have the effects of the elementary, it is equally true that the elementary will have the effects of the electrical. The rays of the sun will put amber and rosin into an attracting and repelling state: the solar fluid being put into motion within the pores of these bodies, produces the same effects with the electrical; and in some particular substances a culinary fire will do the like; though neither of them in any very considerable degree. 3. The light emitted by the attrition of a glass globe, and more especially the spark of the electric explosion, may be divided, by viewing it through a prism, into the seven primordial colours, like the element that flows from the sun, or the light emitted by a common fire; and the streams of this matter, within an exhausted globe of glass, assume all the colours of the rainbow; of which phænomenon, some experiments mentioned in the Optics of Sir Isaac Newton, would afford a good solution. 4. When the solar light passes through a leaf of gold, held up between the eye and a

window,

window, only the *green-making* rays are transmitted; and it is remarkable, that the electrical spark, which issues from a body covered with leaf gold, is of the same colour, though something more dilute. Upon the whole, if these fluids, which thus mutually and in all respects assume each other's offices and properties, are not the same, experiment is a thing not to be depended upon, and the most obvious rules of philosophizing, adopted and approved by all parties, are no better than specious deceptions. That the electrical fluid is the same with that which is sent from the sun in the form of *light*, and gives *heat* to the atmosphere, is still farther evident from the production of *lightning*. After a serene day in the summer, when the air has been exceedingly heated, and the thermometer has arisen suddenly to an unusual height, we are generally sure to be visited with thunder and lightning: in which case, the matter *discharged* from the air in the form of lightning, is undoubtedly the same with the matter that was *accumulated*, and from which the excess of *heat* proceeded. But the matter of lightning, and that in the electric explosion,

sion, are now allowed on all hands to be the same. I have had the opportunity many times of observing this to be the consequence, when Fahrenheit's thermometer has mounted some degrees above 76: and it is a thing commonly known, that a course of hot weather in the summer terminates with a thunder storm; after which the air returns to a more mild and temperate state.

The elementary, solar, and electrical fire then, as we have every possible reason to conclude, are but one substance acting in several capacities. This matter, being lodged within the pores of all bodies, water and ice not excepted, will leave no room for a *vacuum*. The densest of metals are penetrated by it with more ease than the air itself. The farther end of a column, of any imaginable length, will be affected by the same touch that gives motion to the nearer, and in the same moment of time. The same quantity of it that is received into a body, will come forth from it again precisely; and where none can be driven off, none will be admitted; for if the Leyden phial be set on a plate of thick glass, so that the external current from the coating is stopt, it cannot be charged; and

and for the same reason, if, when charged, it be set on glass, pitch, rosin, or any other *electric*, it will retain its charge the longer, and *explode with the greater force* *.

These things being considered, the element of *fire* appears to have such a *continuity* of parts, and such a degree of force in its motions, as would not have been believed without some sensible and immediate demonstrations of it. Yet the same may be proved, without any help from the late discoveries in electricity. It is the same fluid that increases the bulk of bodies when they are heated, by entering forcibly into their pores, and driving their constituent particles farther asunder. The cohesion of brass and iron is too weak to resist the force of it, and, unhappily

* A young man, who served me a year or two as an assistant, and paid no regard to the shock in the common way, was resolved to try in private how this would answer; and unexpectedly received such a stroke, from a phial capable of holding not more than six ounces of water, as laid him upon the floor, and he was not perfectly recovered of it in a month. Since this accident, being myself of a weaker frame, I have never dared to inquire too nicely into that matter. The same person was once struck down in the field by a flash of lightning, which singed his coat; and the symptoms occasioned by these two accidents, as he observed himself, agreed in all respects.

unhappily for the philosophic world, a very small alteration of this kind is easily perceived in the rod of a pendulum. In boiling water, near one *thirtieth* part of its whole bulk, if we reckon only from the point of freezing, which carries us but a little way *, is occupied by fire; for to that degree its specific gravity is diminished, and consequently its bulk is increased to the same degree. Air, under the like circumstances, is increased by one *third* of its bulk. Now, if a quantity of water, with a boiling heat, be supposed to occupy thirty cubic inches; when it is reduced to the lowest degree of heat, with which it retains its fluidity, it will occupy but little more than twenty-nine. Thus its dimensions will be different under all the various degrees of heat; and as the degrees of heat are always in a fluctuating state, this liquid, in common with air and all bodies whatsoever, will undergo a perpetual oscillation.

A question naturally arises, how water, seeing its dimensions are thus alternately extended and contracted, comes to be *incompressible?* Such the philosophers of the Florentine

* Sir Isaac Newton estimates, that water has *above* 40 *times more pores that parts.* See Opt. b. 2. p. 3. prop. 8.

Florentine academy determined it to be, by bruising and battering with a hammer an hollow sphere of metal, filled with water, and exactly closed; for the water, instead of being driven into a smaller compass by this external violence, was seen to sweat like drops of dew through the pores even of gold itself*. So long as the water remains fluid, its parts cannot be in contact; because, if some of the *fire* be withdrawn, they will soon be reduced to a lesser bulk, some force being externally applied upon this occasion by nature itself, with which I hope the reader will be a little better acquainted before I have concluded this Treatise. If more fire were introduced, by heating the water thus inclosed, it would either come forth through the pores of the metal, or burst it all in pieces. Now, as the water itself is *passive*, and may occasionally be comprehended under greater or smaller dimensions, it can be no other than the *agent within its vacuities* that resists the compressing force; and its resistance is so great, that no power of art, or violence of machinery, is

 able

* The Abbè Nollet has a much more commodious way of performing this, mentioned in the 1st vol. of his *Lectures*.

able to overcome it; though nature itself hath a way of overcoming it in a moment.

As some doubt may yet remain, whether it be the element of fire that supplies the interspersed vacuum, (though, in a transparent vessel of boiling water, it may be seen to enter through its bottom in bubbles,) or whether it be some immaterial *repulsive* force; I will try to explain myself a little farther upon this head, and add an experiment or two, which I am encouraged to hope may decide it.

If these spaces then are equally filled with *matter* of any kind, the quantity of this matter will be greater, where the density of the body containing it is lesser; and *vice versá*. If we can prove it to be universally greater and lesser as the rule requires, the conclusion will be undeniable, whether we are able or not to fix the exact proportion of it in every particular instance, which perhaps is impossible. If the rule can be observed to hold good generally and in gross, it is the utmost we can expect or desire.

Water and mercury then are fluids of very different densities: and the water, according-

ing

ing to the rule above mentioned, having the lesser density, and of consequence the greater number of pores, must receive a larger quantity of fire into them, than the mercury will receive into the pores of that, supposing them to be both to have equal bulks and equal degrees of heat. Let water and mercury therefore be taken in equal bulks; let the mercury be hot, observing the degree of its heat by a thermometer; and the water cold, observing also the degree of that. Mix them suddenly; and having stirred them a little so as to render the distribution of the heat equable throughout both the fluids, observe carefully the temperature of the whole by a thermometer. Then invert the experiment in all points; let the water have the same degree of heat that was in the former case given to the mercury, and the mercury have the degree of coldness before given to the water: mix them again; and the heat distributed through them both will be *much greater now the water has the heat given to it, than when the mercury had it.* The latter of these, being the denser, and having the straighter pores, will take a smaller quantity of fire to give it an equal degree of heat; for if heat be no-

thing but the *effect of fire in motion*, and the degree of the heat be as the motion and density of the fire taken together, certainly it will move with the greater violence, and be more compressed within the narrow passages of the mercury than in the wider ones of the water, from whence the whole effect is so easily deduced that it needs no farther explanation. The thing will be found to answer in the same manner, but in a different degree, with spirit of wine and vinegar, or any other liquors, provided their densities are so different as to render the temperature of the mixtures sensibly different upon a thermometer.

All this doth necessarily imply a *transfusion* of some *matter* or *element* from one of the bodies into the other. But, upon the supposition that their particles are expanded by an innate *repulse*, or any *unsubstantial* quality, these effects are altogether inexplicable and contradictory: for, how can a quality be poured, like a liqour, from one vessel into another; or move, like a river, with different degrees of force through channels of different breadths, as the fire plainly does?

Hence also the heat of solids and fluids cannot

cannot consist in the vibratory motion of their own proper particles, but in the action and force of the fluid within their pores: it being against the laws of mechanics, that the particles of *water*, which are fourteen times less in number and weight, should communicate more motion to *mercury*, than the particles of an equal bulk of mercury will communicate to water.

There is indeed a difficulty which some may look upon as a direct contradiction to what I have here advanced. For, as a denser fluid receives into it a smaller quantity of fire to give it an equal degree of heat, how does it happen that, when an iron is red hot, a denser fluid will deprive it of its fire, and cool it more and sooner than a rarer? This is indeed opposite to the rule already confirmed by experiment: yet it is asserted by Dr. Boerhaave in his *Chemistry;* and I know it is a thing generally taken for granted, because it is so agreeable to some opinions vulgarly entertained concerning fire and heat. I thought I could have depended upon the wariness and caution with which that great man usually proceeded in all his inquiries for the truth of this, and was endeavouring to reconcile it: but finding that to be im-

 possible,

possible, I disputed the truth of the fact, and resolved to make the experiment; which accordingly I did, and it fully answered my expectation. I took about five pounds of mercury, the whole of my stock at that time, and having poured it into a crucible, observed the temperature of it by a thermometer of Fahrenheit's scale, and perceived it to be .... 56°

A small cylinder of iron was laid in the fire for ten minutes, till it was red hot; and after it had been quenched in the crucible, the mercury raised the thermometer to 69°

Therefore the increase of heat in the *mercury* was .... 13°

Then I poured an equal bulk of *water* into the same crucible, and found the heat of it to be .... 57°

The iron was laid in the fire as before for ten minutes, and being thoroughly quenched, the *water* raised the thermometer to .... 63°

Increase of heat in the water .... 6°

At a second trial, in which the iron had a glowing heat, the numbers came out, in the *mercury*, 18°, in the *water* 9°.

At a third, when the iron had the best heat I could give it, the numbers were $20\frac{1}{2}$ and $11\frac{1}{2}$.

2 I re-

I repeated the same with a much larger cylinder of iron with a glowing heat; and having quenched it, till it had done hissing, in the *water*, the heat of which was 53°; the thermometer was raised to 150°. The mercury had a temperature of 57°; but when the same iron, heated as before, had been quenched in that, the thermometer was raised beyond the heat of *boiling water*, that is beyond 214°; and by the swiftness with which it moved, I judged it would have gone much beyond the compass of my instrument: therefore I could not determine the exact degree of heat in this case, without making a thermometer on purpose, which was not worth while. From the common result of all the other experiments, the same cylinder of iron, having equal degrees of heat, communicates *twice* as much heat to mercury as to an equal bulk of water; so that the thermometer in this last trial would probably have arisen beyond 240°. Who would have believed that *fire* should have an effect equal to 14, where it ought, according to the common estimation, and the *hypothesis* of a *vacuum*, to have an effect equal only to $\frac{1}{2}$*?

 and

* The specific gravity of mercury being about fourteen times

and that iron, when quenched in so dense a fluid as mercury, should remain so many degrees *hotter* than when it is quenched in water?

Thus we are at length arrived to a conclusion, naturally suggested, and firmly enough established, by a variety of facts; that the heavens are not empty even of the element of

times greater than that of water, the *quantity of matter* in a given space will be greater in the same proportion. Now if there be an *interspersed vacuum* in these fluids; and if fire be nothing more than a certain vibratory motion communicated to their particles; then equal degrees of heat in any ignited body, (as here in the cylinder of iron,) ought, by the laws of mechanics, to communicate *fourteen times as much motion* to a cubic inch of water, as to a cubic inch of mercury; whereas it doth really communicate *only half so much* to the lighter of these, as it doth to the heavier. Therefore the superiority is on the wrong side, and in the ratio of 28 to 1, or 14 to $\frac{1}{2}$. But all this is natural enough, if fire is a fluid *per se*, filling the interspersed vacuities of other matter, and raising a greater degree of heat when it operates in a more confined space.

Water and mercury, being fluids by nature simple, insipid, and uninflammable, are, of all others in the world, the fittest for this experiment. If the same trial were made on oils, spirits, and other chemical liquors, which are inflammable, and impregnated with a *spirituous fire*, more easy to be agitated, many curious and unexpected varieties in the effect might occur, concerning which it may be unsafe to affirm any thing without due examination.

of air; the contrary at least hath never yet been proved, either from the doctrine of resistance, the sinking of a barometer, or any other method: and when the air is withdrawn or excluded, it leaves no *vacuum* behind it, but only resigns its place to a medium of much greater power, whose extensive, and, I may say, universal agency, will afford us a most sublime and intelligible proof of the divine wisdom; and at the same time open to the curious a boundless field for entertaining and useful speculations.

If this be true, are not those physical authors among the moderns, who have rejected, with a sovereign contempt, all subtile mediums, as things fictitious, imaginary, and not worth searching after, hereby deprived of their greatest subterfuge? Bodies, they say, are observed to adhere, to fly from, and approach one another in the void space of an air-pump; and as these effects cannot be imputed to the air, they are not to be imputed (as they have too hastily concluded) to any other *mechanical* agency, but to certain inexplicable virtues which they call *cohesion* and *repulsion*. These are the principles we are now, in the last place, to examine.

CHAP.

CHAP. III.

Of the Physical Cause of Cohesion.

INSTEAD of setting out here with recounting all the minute phænomena of capillary tubes, sponges, drops of quicksilver, &c. &c. which have all been enlisted as so many *undeniable proofs* of an *attraction of cohesion;* though Sir Isaac Newton himself, more modest with all his knowledge than some who have retailed his doctrines to us, proposes none of these with any thing more than a suspicion or a conjecture concerning them; and some of them, as I could easily shew, have not been fairly reported or sufficiently inspected; I desire it may be considered—all the evidence of this sort is *negative*, and owes its whole worth to an arbitrary supposition, that the air is the *only* mechanical agent in nature; and that, merely through the want of another, we must have recourse to immaterial qualities, exerted by the particles of the bodies themselves, there being

being *nothing else** to which these effects can be ascribed.

To all this I oppose the following positive matter of fact, worth an hundred little critical experiments, concerning which much may be said on both sides, while very little is understood on either. It is this—Nature is provided with the element of *fire*, a material agent of sufficient force and subtilty to overcome and undo the strongest effects vulgarly ascribed to cohesion. And as the design of our infinitely wise and bountiful Creator in appointing a material agency, was to build up rather than destroy, to promote and preserve an orderly disposition in bodies, at least as much or more than to cause their dissolution; it is evident to reason, the same agent, acting with some difference of condition and circumstances, must be sufficient to do *both*. The air, when stirred into a tempest, will tear an oak up by the roots; but was this the sole end of its creation? Does not the same air assist the oak and all other trees in their growth? and does it not nourish and preserve many more than it destroys?

Fire,

* See Mr. Rowning's account of the *capillary tube*, in the *Preface* to his System of Philosophy.

Fire, another element, hath in like manner its different offices; and we may hope to gain some light into its more secret operations, if we argue by analogy from one of these to the other. That fire is the great catholic *dissolvent* of nature, the chymists have all been ready enough to confess; that it can *unite*, as well as separate, ought not to be doubted; though it is what few will believe, unless they are possessed of patience and perseverance enough to go through a close inquiry. However, this matter is not so very difficult as they may apprehend.

Let us consider this agent a while in the first and best known of its capacities, I mean as a dissolvent. The particles of mercury, from the sphericity of its drops, should seem to be endued with a strong attraction: yet these particles will cease to have any cohesion, and be separated into fumes by a degree of heat but little exceeding that of boiling water. The particles of water are also said to be endued with the like virtue: yet the agency of fire will very soon relax their cohesion, as appears by a sensible diminution of their specific gravity. The same fire acting with a still greater degree of force, will at length totally dissolve their

union;

union, and raise them aloft in steam or vapour. The ordinary heat of the sun has a like effect on the waters of the ocean. All other substances, as well solid as fluid, are subject to a separation of their parts by the entrance of fire: the hardest of metals, how closely soever their parts may be connected, are easily dissolved and rendered fluid by the heat of a furnace,

Conlabefactatus rigor auri solvitur æstu.

If nature then is provided by its author with an element of such power and activity as enables it to *overcome* the strongest cohesions, it cannot be destitute of an agent powerful enough to *cause* them: if it can do the greater, it must certainly be able to do the lesser. And without much disputing, do we not find it to be thus in fact? For the æther, acting below a certain degree, will consolidate the particle of water into ice: if it acts above that degree, it keeps the water fluid: if to an higher degree, it renders it more fluid: if to an higher still, a total separation of the parts will ensue. But if these parts mount up into the head of an alembic, where the action of the fire is different, they are united again into a well

connected

connected body. These effects being answerable in every instance to the activity and condition of a *material* agent, what necessity is there for calling in the assistance of an unmechanical *attraction?* the work *may* certainly be done without it*; and I am verily persuaded such a principle would never have been seriously defended, if the agency of fire had been searched into as it deserves. If I can see the effects vary as oft as there is any change in the element of fire, I am compelled, by all the rules of reason and philosophy, to understand this element as an immediate *cause* of these effects, and must receive it as such, till it is demonstrated to be inadequate; the contrary to which hath been demonstrated already, and might be farther confirmed by some other experiments, which I might here introduce, if there were any occasion for them.

The cohesion of bodies by the action of this fluid, may be illustrated and confirmed in a familiar way by some parallel effects, in the explication of which we are all agreed. Let a stop-cock be fastened to the neck of a bladder, that it may be screwed upon the

work

* *Entia non sunt multiplicanda absque necessitate.*

work of an air-pump: exhaust the air from it; and having turned the stop-cock, to prevent the air from re-entering, take it off the machine*. The bladder is now transformed into two flat skins, so closely applied together, that the strongest man cannot raise one of them half an inch from the other: for, supposing the bladder to form the area of a circle six inches in diameter, each side is pressed down upon its fellow, with a force equal to 396 pounds. On the contrary, if the bladder be blown up with air, and the stop-cock turned to prevent it from getting out, it will be more difficult to bring the sides together, supposing them not to be rent in the attempt, that it was before to separate them.

I must be allowed to put a case here. Suppose a person, presented with this spectacle, to be unacquainted with the pressure of the atmosphere, as many people undoubtedly are, and many of the learned also were but little more than a century ago; what

* This will answer as well without the formality of an air-pump. Only let the sides of a bladder be pressed flat together, while the neck of it is tied fast to keep out the air.

what will such a man say, when he is pulling at the sides of the bladder, and finds it impossible to lift up either of them? If he is illiterate, he may think perhaps they are bewitched; if he has any knowledge of philosophical terms, he may say, "Nature abhors a vacuum:" if he has any faith in the modern doctrine of a vacuum, he will take this to be an undeniable proof of a very strong *attraction.*

When the bladder is blown up, (allowing him still not to be aware of any fluid within it,) he must say the sides *repel* one another; or he may call them *elastic*, attributing that elasticity to the solid matter of the membrane itself, which is the property of the invisible medium inclosed within it.

Attraction and repulsion, as here applied, are the creatures of this man's imagination, to say nothing of his ignorance. If he is fond of his fancied discovery, he will give himself no trouble about the real cause of these appearances, for he thinks himself to be already in possession of it; and will not perhaps be very well pleased with those who endeavour to go farther, "for ever asserting his right to stop, where he finds he

"can

"can get no farther upon sure ground*." Many philosophers were grievously disappointed, when the pressure of the air was established by experiment; the learned Dr. Henry More in particular, who opposed Mr. Boyle and Professor Sturmius with great vehemence upon this article. He had long indulged himself in the belief of an *hylarchical principle, a spiritus mundi hylostaticus*, which he describes as a *living plastic nature*, but *brute and unintelligent*. And thus he solved, without any more expence than that of pen, ink and paper, all the appearances of the visible creation.

We are apt to wonder, in these days, how men of learning could thus supinely acquiesce in a set of occult and barbarous sounds, and be ignorant of the weight of the atmosphere, to which an experimental inquiry must inevitably have directed them. Yet our own practice at this time is in some respects no better than theirs; we have ascribed an oracular dignity to a term, which has either no meaning at all, or many contradictory ones; a word that explains no more than the *principium hylarchicum*, and not

* See the *Preface* (of the editors) to Mr. Maclaurin's account of Sir Isaac Newton's discoveries, p. 16.

not quite so much as the *abhorrence of a vacuum*—But let us return to experiment again.

Instead of the bladder, let us now take two concave brass hemispheres, known by the name of the *Magdeburgh hemispheres*, and first invented by Otto Guericke. They afford an appearance of the same kind, but more convenient to our purpose at present. Apply these hemispheres to each other: if you squeeze them ever so hard together with your hands, they are easily separated afterwards, and most probably will fall asunder by their own weight. What is the reason of this? Every fluid, we know, will naturally be *in equilibrio* with itself: the air, being here applied both to the inner and outer surfaces, will press with equal and contrary forces; which only destroy one another. But if the air be exhausted from within, there will then be an excess of pressure without, by which the hemispheres will be firmly fixed together. After this, if the air be again admitted, they will fall asunder as before.

Thus then let us argue: that as the air, when it enters, puts an end to this adhesion by restoring an equilibrium, it is plain there was not an equilibrium before: the action from

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within, must have been weaker than the action from without, if the effect ceases when the former of these is made equal to the latter. And I desire the reader to observe, that the offices both of *uniting* the hemispheres, and *separating* them, are exercised on this occasion by *one and the same fluid.*

If this reason is just, the transition from the surfaces of the brass hemispheres, to the cohesion of the brass itself, will not be very difficult. For, let this brass be thrown into a furnace, it soon grows red; and as the heat increases, it becomes in a manner transparent: the matter of the fire penetrates into the body of the metal; and when the medium within is nearly in the same condition with the medium without, the brass runs, and there is an end of its cohesion. An effect which is thus made to cease in a mechanical way, may be produced in the same way; and if the entrance of the fire (as we argued above) dissolves and separates the parts of the metal; the exterior pressure of the same element, though in a different condition, was the true cause of their cohesion.

Deny the existence and pressure of the air,

and you must have recourse to attraction, or suction, or an incorporeal agency, to account for the adhering of the hemispheres. Allow but the existence and pressure of elementary fire, the reality of which is manifest to as many of the bodily senses as the reality of the air; and you need not have recourse to any of these things to account for the cohesion of the brass.

Between these two effects there will be a nearer and more apparent resemblance, if the hemispheres, instead of being evacuated by the machinery of a pump, are heated moderately at a fire. The more subtile fluid, rushing into the concavity, expands and takes the place of some of the grosser air, or *rarefies* it, as we commonly speak. In this state let them be applied, with a luting of any kind to the joint, and dipt in cold water: they will adhere as effectually as if part of the air had been withdrawn by exsuction. In like manner, when the fire dissolves a mass of metal, an extremely fine and subtile fluid passes freely through the body of it: but as it cools, this medium within, having no fresh supply, evaporates in part; and the remainder, growing continually weaker, yields to the superficial pressure

pressure of the same element, in a colder and less rarefied state: from whence the whole effect must follow in a natural way; and the agent which drives the parts together, being universally present, will keep them together, till it is again counteracted as before. If any experimentalist shall hereafter be able to exhibit one single instance of a cohering body, where he can prove the internal and external pressures to be *equal* in all respects, we may then grant him his attraction; we may confess, such an effect is not brought to pass in a *physical* way; and that we understand no more of the cause of *cohesion,* than he has expressed under that *word;* which is just nothing at all.

In the mechanical way of solving the cause of cohesion, of which I have thus ventured to offer a short draught, I perceive there is one article that wants to be explained and confirmed a little farther. It will be granted me, I presume, that the matter of fire, by penetrating through the surface of a solid or fluid body, acts *internally* with an expansive force, to loosen and drive asunder its constituent particles. But where shall I find a medium to act *externally,* and over-

come this motion of the fire when the body grows cool and begins to concrete? If I should say, the *heat* within is counteracted by the *cold* without, and that cold is the agent acting externally, it will be asked again, how cold, a mere *privation*, can be taken for an agent? But that cold is a mere privation, I cannot believe, because experiment shews it to be the effect of a cold ætherial fluid, as heat is the effect of fire, an hot fluid. I cannot stop here to pursue this so far as it deserves: it will serve my purpose at present to prove the reality of a *cold æther*, different from common air, and of sufficient power in its operations to execute the office I have assigned it.

Spring-water, it is well known, contains in it a large portion of air; and most of the medicinal waters, such as Pyrmont, Bristol, Tilbury, &c. contain much more than the water of common springs. But there is an easy method of extracting all the air, so that no part of it shall remain. This is done by boiling the water, and then placing it within the vacuum of an air-pump. When it has remained in this situation till it is cold, it is sufficiently purged of its air, and ready for the experiment I am about to propose.

Pour

Pour some of this water into a small glass phial with a long and slender neck; observing withal, that the surface of the water is to reach no higher than to the bottom of the neck. Set this phial on a small transferring-plate, and cover it with a glass receiver, from which exhaust the air as perfectly as possible. Then plunge the receiver, with its included phial of water, into a freezing-mixture, composed of snow or beaten ice mixt with common salt, or powdered *sal ammoniac*, which is better. In a very little time, your phial of water will be frozen into ice, which runs much higher into the neck of the bottle, and occupies more space than the water did in its fluid state. This intumescence, as you will perceive upon inspection, is owing to a great number of *bubbles* dispersed within the body of the ice, which certainly are not composed of air; for air does not swell and rarefy with cold, but is always condensed into a lesser space. Besides, there was no air either in the water or the phial, neither can air penetrate the glass of the receiver; and if a small gauge be included together with the phial, and the ice be melted after the operation of freezing, by bringing the receiver near a fire, these bub-

bles will rise up and burst at the surface, as the ice grows liquid; but after all, the gauge will not be affected by them, as it would be if they were of the same nature with common air. When the ice is all reduced to water, and wholly cleared of its bubbles, repeat the freezing; you will perceive the same intumescence as before, and the same collection of bubbles; and thus it will happen *toties quoties*; as I can venture to say, because I have been at the trouble of making this experiment, so far at least as to satisfy myself of the truth of what I assert.

This subtile æther, though but small in quantity when compared to the bulk of the water is introduced with a force which art would find it very difficult to measure; a force capable of bursting strong vessels of silver and brass, such as might be filled with air many times condensed, without receiving the least damage. The experiments of this kind, made in the Academy del Cimento *, do well deserve the attention of those

* See their experiments on *artificial-freezing*, p. 69, &c. But lest it should be thought, that the effects, I here refer to, were owing in any degree to common air, I must beg leave to subjoin the following experiment; I made a strong cylindrical

those who require any farther satisfaction in this matter; and to these experiments I refer, as to so many proofs of an æther, cold, subtile, adequate to all the effects of cohesion, and different from common air.

It

cylindrical box of metal, with a broad rim, to which a flat cover was applied so exactly, by grinding one upon the other in a turning-lath, that when the cover was laid upon the box, no light could be seen through the joint. Then I prepared some water, by boiling and placing it upon an air-pump. This water, when cold, was so thoroughly purged, that it would not yield the least bubble of air, when the pump was well evacuated; and this I tried immediately before the using of it. I filled the box with some of it, till it stood convex above the rim: and having applied a wetted leather to the cover, screwed it down firmly upon the box with four iron screws; by means of which, it was made *air-tight*: and in this state, I suppose, the box and cover would not have been separated by a weight equal to half a ton, and perhaps not by a great deal more. Having plunged the whole into a freezing mixture, the water was frozen into a solid mass in less than half an hour; and as its bulk increased, by means of the inclosed bubbles of *cold*, three of the screws were forced by the violence of the pressure, and the cover was raised up on one side, about a quarter of an inch above the rim.

Common air, it is certain, could have no share in this effect; the whole being occasioned by a finer *æther*, so small in quantity that it did not occupy a cubic inch, and so great in force that its pressure must have been an *hundred times* greater than that of the atmosphere, which is only *fourteen pounds* upon a surface of an *inch square*.

It is true, I am not confined to these; there are many other ways of proving the same thing; and the phænomena of electricity have have served to open the eyes of some few experimenters; so that I have the satisfaction to find I am not singular in assigning a *mechanical* cause of cohesion.

The ingenious Mr. Wilson, F. R. S. in his *Treatise on Electricity*, p. 187, is of opinion, "that cohesion may arise from the "mutual action of the *light contained within* "*bodies*, and of the atmospherulæ surrounding them, the pressure of which alone "may be sufficient to make their particles "cohere with a great force, &c." Dr. Boerhaave also hath dropt an hint, as it were by accident, which greatly favours what I have advanced: "If, therefore, (says he,) *cold* "were a mere *privation* of fire, the power "which *contracts* the particles of a solid "body would be innate, or implanted in "the nature of body itself; while the power "that *expands* would depend upon the "fire, and consequently be something extrinsic." See Boerh. Chym. by Shaw. Vol. 1. p. 219. He seems here, to me, to mention this as an absurdity in nature. And surely it is incredible that bodies should

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be *relaxed* by the force of a *medium*, and *consolidated* by an *attraction* in the matter: in other words, that the particles, of which they consist, should be moved outwards from A to B by a mechanical force, and brought back again from B to A by an occult quality. Would this be agreeable to that uniformity which is every-where to be observed in the ways of God? it must follow therefore, according to the suspicion of this author, that cold is not a privation of fire, but occasioned by something as *real* * and positive, as that *fire* which is the occasion of *heat*. I say no more in this place, having considered this point particularly in the ensuing pages.

There is another sort of reasoners amongst us, who seem to glory in their ignorance; and have precipitately defied *all the philosophers upon earth, to account for* cohesion, *otherwise than by the power of the Deity immediately*

* Plato is very clear upon this article, in the discourse of his *Timæus Locrus*—Το μεν ων θερμον, λεπτομερες τε και διαστατικον των σωματων δοκει ειμεν. Το δε ψυχρον παχυμερεστερον πορων και συμπιλωτικον εστι. "What we call "heat, consists of very fine parts, which serve to separate "and dissolve bodies: but *cold* is made *of grosser parts*, "which press upon and stop up their pores." *Plat. Op. Serr.* vol. 3. p. 100.

mediately interested. After the extravagant lengths these gentlemen have gone, for the sake of gaining some credit to I know not what metaphysical reveries, they must be endued with a degree of candour and ingenuity rarely to be met with, if they will attend to any thing of this kind. But I must beg leave to remind them, that if they will account for cohesion by immaterial impulses and miracles, they should account for the adhering of the two exhausted hemispheres after the same manner, and deny that the air is employed as an instrument in this business. For I humbly think, it is consistent neither with the wisdom nor the power of God, that he should ordain an inanimate substance to produce some effects, and produce other similar effects by the immediate influence of his own divine essence, because they are conceived to be beyond the reach of any instrument even of *his* contriving. Such a conclusion as this, no pious man, who is really concerned for the honour of God, can easily digest; and Mr. Boyle, I am persuaded, would never have admitted it. Nature is extremely simple in its agency, though infinitely various in its productions: it is not made to

act

act by corporeal impulses for the production of some effects, and by attractions and spiritual influences for the production of others. Of this simplicity in nature, if we can trust to their own declarations, philosophers of all ages have been persuaded; and it is no fault of mine, if some of them have unhappily departed from their own rules, and made nature to abound with almost as many causes as effects.

CHAP. IV.

An Experiment *to confirm and illustrate what has been advanced in the foregoing Chapter: with some Observations on* Heat *and* Cold.

I Should very far exceed the bounds I have prescribed to myself, were I here to run through the natural history of cohesion, and distinguish all the variety of cases I have collected, some of which may be intricate and difficult enough, whilst others would serve to clear them up, and confirm the principles I have advanced. I cannot however forbear to select one example, as it seems

seems to yield us a palpable proof that cohesion is caused in the manner I have supposed.

There is a toy made in our glass-houses, which the learned have treated of under the name of *lachryma vitrea;* the workmen call them *glass pears,* and they are commonly sold in London for the diversion of school-boys; though they are attended with a phænomenon which hath excited the admiration of most of the philosophers in Europe. They are made of the ordinary green glass, by letting fall a large drop of it, when in fusion, into a vessel of cold water. If a piece of the neck be afterwards broken off from the drop thus prepared, the whole body of it bursts asunder with an explosion, and is split into a thousand small fragments, which may be crumbled into dust without any injury to the fingers. This effect, wonderful as it is, may easily be traced up to its cause.

It was observed above, that as a melted metal grows cool, the fire that had been lodged within it evaporates by degrees; while a colder æther, pressing on the superficial parts, brings the whole to a due firmness and coherence. Here we have a noble illustration

illustration of it. The fire, having rarefied the particles of the glass, and put them into a state of fusion; the cold, applied suddenly by the water to the superficial parts of the drop, forms a condensed crust of glass over the whole, before the fire within has time to escape in a regular way. By this means, the inner particles are closed up in their rarefied state; and when all is cold, there remains between these particles, what custom, and the poverty of language, obliges me to call a *fire-vacuum*, analogous to the vacuum of an air-pump. When a piece is broken off from the smaller end, a part of the *rarefied core* is immediately exposed, the interstitial passages of which are so open as to admit an æther that ought to have been stopt by the surface: this æther rushing in suddenly, as air into an exhausted vessel, fills the pores with such violence as to rend the whole substance into atoms. The channels formed by the disposition of the pores, must likewise be of such a figure as will contribute not a little to the success: for, as the matter of the glass decreases in its rarity from the axis of the drop toward the circumference, all these channels will represent the figure of a *wedge*; the propriety of which,

in this case, and the consequences that must attend it, are clear enough.

It is not *air* that occasions this effect, because it will answer best *in vacuo*, and, what is very much to my purpose, it is then attended with a flash of *light*; for the observation of which curious circumstance, we are indebted to the French academy*.

In some trials, the progress of the effect hath been such as plainly to point out the true and natural solution of it. Franciscus Redi, who published forty-one different experiments upon these bodies, without adding one word of inquiry after the physical cause, informs us, that when he had coated one of them with plaster of Paris, leaving out some part of its tail to be afterwards broken off, the coating was rent by the explosion at the basis of the drop; "as if the "force of the fracture took its rise at the "extremity of the tail, and passing down-"ward from thence to the basis or bottom, "forced away the plaster of Paris in that "place†."

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* *Hist. de l' Acad.* 1692. p. 307.

† Guttula rumpendo vim basin versus faceret, & in eâ parte laceraret gypsum, ac si vis rapturæ originem caperet a principio caudæ, iretque semper impellendo versus basin aut fundum guttulæ. *Redi Observ.* p. 61.

It is farther remarkable, that if one of these bodies be laid upon hot coals, or boiled in oil, and doth not burst in the operation, (which very frequently happens,) it is reduced to the temper of common glass, that hath been regularly *annealed;* and if its neck be snapped off, the usual event does not follow. The fire relaxes the indurated crust, and, having gained a passage through it by slow degrees, fills up the pores of the glass without violence; after which it grows cool with a more equal and regular disposition of the parts.

If these things should not appear to others in the same light as to myself, I cannot help it. I leave it to be considered, whether we should not come much nearer to an agreement, if, instead of attempting to annihilate the agents God hath created, they would spend some labour upon the study of them, and examine the wonderful effects of the ætherial elements, without a resolution to find attraction and a *vacuum*, where no such things ever existed. The effects of heat and cold, as daily exhibited to our senses in the customary changes of the weather, are sufficient to justify me in what I have

have deduced from them. When the weather grows warm, the power of cohesion grows weaker; when the weather becomes cold, this power is increased; and the hardest of metals, in common with all other bodies, are proportionably altered in all their dimensions. Extreme heat will dissolve them; extreme cold will harden, and render them so brittle, that large bars of iron may be easily snapt in sunder, after they have been exposed all night to the open air in a severe frost. A power of so fluctuating a nature, and which is thus rendered greater and lesser with every change of the elements, can be no property of the cohering matter.

If the changes of the atmosphere are found to make the heights of the mercury in the barometer vary, who can doubt that the *pressure of the air* is the sole and adequate cause of its suspension? and accordingly, if the air be totally removed from the surface of the cistern, the mercury drops to a level with it. Therefore it hath never once been suggested to us, that mercury is endued with the property of flying up into a glass tube.

Thus also, if the degrees of density in a cohering body, vary with the degrees of heat

and

and cold; where should we seek, but in the element of fire, for the true and physical cause of cohesion? when we descend indeed to the precise mode of its operation, it is hardly to be expected our ideas can have a mathematical exactness. I take it for granted they are very gross, and such as we should be ashamed of, if the sense of man extended to the first principles of matter, which God, in great wisdom, hath purposely placed out of his reach. But it is no inconsiderable step in philosophy, barely to determine the question, whether God hath chosen to act by material instruments, or immaterial influences: it being of the utmost importance in every science to begin rightly, and have our labours directed into a proper channel.

As it will probably be much doubted whether the operations of heat and cold are to be ascribed to elementary fire, as to one and the same substance; that matter, I think, may easily be adjusted by observing what happens to a common thermometer. When you bring it near a fire, and find it rises from 55 degrees, the point of temperate, to 212, the degree of boiling water; to what substance do you impute this, and what is your name for

 it?

it? doubtless you will tell me, it is elementary *fire*. Suppose the thermometer to be falling 32 degrees below the point of freezing, and to be raised from thence up to temperate; during the greater half of which motion, a very severe *coldness* is predominant. Now, if you imagine heat and cold to be things different in their nature, you must provide one element to raise the thermometer through the upper parts of its scale, and another to raise it through the lower; and after all, you will never be able to guess at any point of distinction, where the one ends and the other begins. For if your instrument, when exposed out of doors, should stand at 55 degrees in January, the air would be attended with a very sensible *warmth* to the body, and you would find yourself able to sit very comfortably without a fire. If it should stand at the same point in July, you would complain of shivering with *cold*, and perhaps order a fire to be lighted. Thus you will give the contrary appellations of *hot* and *cold* to one and the same temperature of the air; and if you realize these different ideas, which arise wholly from a deceived sensation, and search after a species of *frigorific particles*, *acids of the air*, and

and such like, you discover nothing real in nature, but become the dupe of your own language.

Heat and *cold* are the names we have given to the sensations which are raised in us by the different (and sometimes by the *same)* impressions of elementary fire. If an effect is produced when the thermometer stands at the heat of boiling water, I call it *fire* that produces it: if water is frozen into ice, and the thermometer stands at 30°, I am sensible of cold in my body, but the agent in this case is elementary fire; and there may be a greater philosophical propriety than we are aware of in that expression of Virgil—*Penetrabile frigus adurit* *. As we do not look upon *air* to be one kind of element when the barometer sinks to 28 inches, and another when it rises to 31; the element of *fire* ought to be considered in the same way, under all the different stations of the thermometer, that is, all the different degrees of heat and cold.

Upon these considerations, I have followed the most eminent of the chemists, and some modern writers on electricity, in using

* Georg. L. I, 93.

the word *fire* in its largest sense, when I mean either *fire*, or *light*, or *æther*. We may indeed call it by any of these names, because the same fluid must be understood by every one of them: though, if we were to stand upon strictness and propriety of expression, it would be necessary, on some occasions, to use the first of these; on others, only the second or the third. When this fluid is cold and invisible, or appearing only in pellucid bubbles like air, as in the *freezing experiment*, let us call it *æther*— "cæcus ignis expers luminis*." When it becomes visible and lucid, it is what all men have agreed to call *light*. When it gives heat and burns, it is *fire*. The employment most agreeable to me, is to search after *things*, and try to render *them* intelligible: if I can but be so fortunate as to make some little progress in that respect, I leave the reader to correct my expressions, and settle the application of words at his own discretion. If he has had patience enough to follow me thus far, I hope he will hear me out, while I examine the nature of another sort of power, opposite to attraction, and distinguished by the writers of these times under the name of *repulsion*.

CHAP.

* Du Hamel.

CHAP. V.

Of the Physical Cause of Repulsion; *particularly as this Principle is applied to the* Elasticity *of the* Air.

IT is needless to repeat all the instances commonly urged, either to illustrate the operation, or prove the reality of such a principle as *repulsion*. The best-known, and most universal of these, is the *elasticity* of the *air*; the property by which it resists any compressing force, and which the great Sir Isaac Newton, and others, have endeavoured to account for, by supposing a *repulsive force* to be implanted in its particles: for thus, it is presumed, they may drive each other farther off, without the intervention of any other matter *.

If *repulsion* is proposed to us, as a discovery of the *cause* of this property in the air,

* "Which vast contraction and expansion (of the air) "seems *unintelligible*, by feigning the particles of air to be "springy and ramous, or rolled up like hoops, or by *any* "*other means than by a repulsive power*." Newt. Opt, Q. 31.

common sense will remonstrate against such an imposition. Experience will teach us, that the particles of the air are by some means or other repelled to a certain distance, and cannot be forced into immediate contact by any power we are acquainted with. To inform us this is owing to a *repulsion*, is but to tell us (by using the noun substantive instead of the verb) what we knew before, namely, that the particles *are repelled.* Repulsion is the *fact;* the *cause* of repulsion is still to be inquired after.

Mr. Boyle, always ready to offer some mechanical solution of what occurred to him, supposes the aerial atoms to be a sort of elastic spirals, like *watch-springs*. Thus they may resist any incumbent pressure, and naturally restore themselves to their former state when that pressure is removed. Bernoulli, who studied the æther in a mathematical way, gives up this whole affair as an *inexplicable mystery of nature* *, when his own principles might have helped him to understand it: and Du Hamel, a famous Cartesian, embraces the hypothesis of Mr. Boyle, as absolutely *necessary* †.

But if some circumstances are laid together,

* *De Gravit. Æther.* p. 81.

† *De Consensu Vet. & Nov. Phil.* p. 229.

ther, this necessity will soon disappear; because, if it be admitted, it will carry us into very great absurdities. The steam of boiling-water, as we find by its effects, is equally elastic with the air; and is therefore applied to give motion to a fire-engine for draining the water out of mines, in the performing of which a very great power is requisite. The force of this steam in Papin's digester is incredible; and, without due caution, would burst the strongest vessel. In the Æolipile, it appears as an extemporaneous air, and its *elasticity* is as manifest as that of the air. Are the particles of *water* then of a spiral-like form? and is this supposition *necessary?* If it is not necessary to account for the elasticity of water, it cannot be so to account for that of the air. Fire, which acts upon the former of these, and, by expanding, renders it elastic, may produce the same effect in the other *. It would be absurd to feign a set of springy particles in water; this fluid in its ordinary state being reputed unelastic: and in fact, no author I have ever met with hath been so unreasonable as to suppose

* Aquarum enim quasi vapor, quidam aer habendus est, Is autem existit *motu ejus caloris*, qui aquis continetur. Cic. *de Nat. Deor.* L. 2. 10.

pose such a thing. The particles even of mercury itself, ponderous as it is, when sublimed by the impulse of fire, become elastic like air or water, and will burst the vessel in which they are confined. When a drop of mercury is thrown into a naked fire, it hisses and explodes like water. Is *mercury* also composed of springy particles; or rather, do they not manifestly borrow from the impulse of fire all the elasticity they are endued with? For if the agency of the fire be suddenly checked, the elasticity of mercury, of water, and of air also, in its proper degree, departs together with it.

THE true cause of this elasticity hath been acknowledged by some ingenious men, whose labours were sure to be attended with some success, because they argued with facts before their eyes, and endeavoured to examine them to the bottom. It is greatly to be wished, that all philosophers would do the like. Dr. Shaw, in his useful notes on Boerhaave's Chemistry, assures us, without any hesitation, "that the active force in *air*, which "produces so many effects, does really *all* "arise from the *fire* contained in it *." And

Dr.

* Vol. I. p. 220.

Dr. Alex. Stuart, in his Lectures on muscular motion, which contain some curious observations in anatomy and physics, has the following words—"Thus it appears that this expan-"sion and *repulse* is not owing to the natural "elasticity of the air, but to a foreign power, "to wit, that of *fire* acting upon it;" which the author classes among the species of *fluids, visible and obvious to the touch* †.

If it should be suspected that I am taking refuge under the authority of others, and would thus impose a belief of what may not very easily be demonstrated; only let a bladder, half filled with air, and closely tied about the neck, be brought near a fire: it will immediately swell; and the elasticity of the inclosed air will increase, as the action of the fire upon it increases. If a bladder were blown quite full of air in the heat of summer, and preserved till the depth of winter, it will have lost much of its elasticity, and be shrunk into a smaller space. Thus, if a greater degree of motion in the fire gives *more* elasticity, and a lesser degree *less* elasticity, to the same quantity of air; the element of fire appears to have the direction of this property, and is the immediate physical cause

† Philos, Transact. abridg. by Martyn, vol. 9, p. 285.

cause of it at all seasons. That fire is always intermixt with air in a certain proportion, is evident from the thermometer.

This whole affair seems to be in a manner so self-evident, that it would be idle to insist upon it any farther. However, there is a powerful objection or two, to which I have never yet seen any reply: and certainly they deserve to be carefully examined, because they have been thought to countenance the doctrine of *repulsions*, *springy particles*, *&c.*

It is observable, that a flaccid bladder, placed under a pneumatic receiver, will be distended when a part of the air is withdrawn from the outside of it, after the same manner as if it were held before a fire, but in a much greater degree. If fire is the immediate cause of this property, how can the repulsion increase, when the heat does not increase?

Mr. Boyle hath intitled this—" a disco" very of the admirable rarefaction of the " air, *even without heat**." But this is not a just and proper representation of the case: it should have been said " without any *additional* heat," and then there would have been no obscurity; an additional heat being not

* See Bolton's abrigd. V. 2. p. 249.

not requisite upon this occasion. We need only appeal to a thermometer placed within the receiver, to prove the degree of heat *there* to be the same as without in the circumambient air. This heat is sufficient for the purpose, and will necessarily produce a rarefaction within the bladder, when the vessel that incloses it is exhausted.

So long as the receiver is full of air, of the same temperature with that in the bladder, there are two equal forces counteracting one another: there is air within the bladder, rendered elastic by the standing degree of heat at that time in the atmosphere; and there is air equally elastic, pressing externally, and with equal force, on the outer surface of the bladder: so that while things remain in this state, all will be at rest. But the effect will be just the same, whether you *add* more heat to the *inside*, or *take away* an equivalent degree of the resistance from the *outside*: a rarefaction must follow upon either of these changes; and as fire is always exerting its force, it is easy to predict what the event will be, and what in reality it is found to be, when the resisting air is withdrawn. For suppose two men, of equal strength, were pushing, one on each side, against the door

door of a room, which will open either way: it will be the same in effect, whether you add another man on the inside, or take away your man from the outside; the door will be opened *outwardly* in either case. And thus it happens to the flaccid bladder upon the air-pump: to subtract the resistance from its outer surface, is the same as to add a greater force of expanding fire to its inner.

A second objection, which hath a plausible appearance at first sight, is drawn from this observation, that the air in a flaccid bladder, carried up to the top of a mountain, will be expanded; when, if fire be the cause of its elasticity, it ought to be contracted; the air being much *colder* there, than in the valley below. This is nothing more than the former experiment under a new shape, and with the addition of a fresh circumstance. When we ascend a mountain, the barometer sinks: that will cause the bladder to swell. At the same time the cold increases: that will cause it to shrink. It is to be inquired, then, what proportion these opposite effects bear to one another. The result will be, either two equal quantities, or two different ones. If the quantities were equal, the bladder ought still to preserve its dimensions: if they

they should prove to be unequal, the lesser must be subtracted from the greater, and the effect will be equal to the remainder.

In order to adjust this matter from experiment, I find myself under a necessity of informing the reader, that I once made an excursion into the Peak of *Derbyshire*, with the hope of improving my health, and adding something to my little stock of botanical knowledge. I took this opportunity to examine the height of some of the mountains in the peak with a portable barometer, which I had made for this purpose, after the pattern of that described by Scheuchzer in his *Itinera Alpina*, with some little improvement. To this instrument I added a mercurial thermometer, graduated according to the scale of Fahrenheit. Upon one of the highest of these mountains, the barometer stood very nearly an inch lower than at the surface of the river which runs at the foot of it. This was in the beginning of June 1760, and the air was unseasonably cold, the thermometer standing, at noon-day, below the point of *temperate*. I must confess, the objection now before us was not then in my thoughts; otherwise I should have been more exact in my remarks: but, to the best of my remem-

brance, the difference I observed in the thermometer, when I had ascended the top of this hill, amounted only to 2 degrees.

Since that time, I had occasion to prepare an instrument, which performs the offices both of a thermometer and barometer, and renders all the momentary changes of the atmosphere evident to sense; for when it is exposed to the shaded air, it is never at rest, but shews such a perpetual agitation of the elements, as might suggest many useful and pleasant reflections; but they are all wide of my purpose upon this occasion. It is sufficient to observe, that when the barometer sinks 1 inch, the spirits in this instrument rise 15 inches perpendicularly in the tube: when the thermometer sinks 2 degrees, the spirits sink $2\frac{1}{4}$ inches. The motion of these spirits being occasioned only by the swelling and contracting of some inclosed air, we thus find, without much trouble, what difference there is between the two contrary effects above mentioned. The *expansion* of air, included in a bladder, and conveyed from the bottom of that mountain to the top, should have been nearly as 15, on account of the sinking of the barometer, and the lessening of the incumbent pressure; while

while its *contraction*, on account of the increasing cold, would have been only as $2\frac{1}{4}$; which being deducted from 15, leaves $12\frac{3}{4}$ to express the *real* expansion of the air, instead of 15, which we may call its *potential* expansion. This difference is so small, and takes so little from the effect, that it would never be thought of in so gross an experiment as that of the bladder: and the higher the mountain is supposed to be, the less would any such interruption be taken notice of. A barometer would fall about 4 inches below its mean station, at the top of a mountain, 1320 yards, or $\frac{3}{4}$ of a mile above the level of the sea; at which height, the cold is usually so great, that the snow lies continually. Let us suppose, that a thermometer, conveyed in the summer-season from the foot of such a mountain to the top of it, would fall from 60 degrees to 32, the point of freezing. The expansion of some air, inclosed in a bladder, should be as 60: but its contraction by the cold will be as $31\frac{1}{2}$; therefore its real expansion would be as $28\frac{1}{2}$; and a flaccid bladder, instead of shrinking into a lesser compass with so great a degree of cold, will still be expanded *more than*

twice as much as in the foregoing experiment.

These considerations have made me easy in regard to the immediate cause of the air's elasticity. I heartily wish they may have the like influence upon others, and get the better of all their scruples. If fire, that universal and active element, can occasion such a property in the air, by a mechanical and impulsive motion, the thing is intelligible. By this means we become possessed of one important truth in natural philosophy, and such as may in time direct us to many others. Could it once be shewn, that air, totally emptied of its fire, has any of this elastic property in it *, it would then be time enough to call in the assistance of *repulsion*, which is but the same thing with giving up the point as unintelligible. But unless elastic air can be exhibited under such circumstances, (which cannot be, unless the thermometer be first made to sink 290 of Fahrenheit's degrees below the *freezing point*,) there is no more occasion for this quality than for that of cohesion.

To

* Non tantum aer in ignem transit, sed *nunquam sine igne est*. Detrahe illi calorem, rigescet, stabit, durabitur. Senec. Nat. Quæst. lib. 3.

To those who examine this matter impartially, these powers will appear incredible in their very nature. The effects which are explained by attraction and repulse, do so often vary, that we are obliged to suppose the same particles of matter endued with both; with one virtue of drawing and alluring bodies, and another of terrifying and driving them away at the same time. But how, in the nature of things, can two principles, destructive of each other, reside in the same subject? Repulsion is as opposite to attraction, in my way of conceiving it, as darkness to light, or cold to heat; and it is equally impossible that the same particle should both attract and repel, as that it should be both black and white, hot and cold, at the same time. To reconcile this, some have invented several concentric spheres, or *involucra* of contrary powers, surrounding the same atom of matter; so that when other matter approaches the atom, thus invested, as it were, with the coats of an immaterial onion, it meets first with a repelling sphere; being forced somewhat nearer, it falls in with an attracting sphere; and coming yet nearer, it meets with a repelling sphere, to keep it from immediate contact. What a complication of causes is

 here!

here! and all to make one poor atom vibrate through less than the 1000th part of an inch! This can never be agreeable to that simplicity of nature, so much boasted of by all philosophers; and if our own senses are to have any weight, the experience of every day might lead us to something more true, useful, and intelligible.

CHAP. VI.

The Application of Cohesion, *as an* unmechanical *Principle, serves only to keep us in Ignorance. This is proved from a plain Example.*

TO bring the argumentative part of this book to a conclusion, I shall take the subject of *vegetation*, and compare it with the favourite principle which hath been applied of late years for the explanation of it by our systematical writers; in order to shew, by one example out of many, that these powers, which have unhappily been substituted in the place of the true agents, do not only not explain

explain any effects, but tempt us to conceive falsely of nature, and to affirm what is contrary to experience. My only reason for driving the argument thus far, is to encourage those, who pretend to be guided by *experiment*, to endeavour at some farther progress, and not *for ever assert their right to stop*, when they might go farther on with pleasure and safety.

When a glass tube of a very small bore is dipped into water, or any other fluid except mercury, the fluid will be raised to a certain height within the tube above the surface of the liquor in the vessel; and its elevation, in several tubes of different sizes, will be *reciprocally* as the diameters of their bores.

The ingenious Mr. Rowning will have it— "it is drawn up *by a tendency* it has by the "principle of *attraction*, till the surface is "loaded with as great a weight as that *ten*"*dency* can support *." Not to take advantage here of the author's terms, (which to be sure are unintelligible,) let us for a while agree with him; and suppose the inner surface of the tube to *attract* the water. "*Hence* (says he) a RIGHT NOTION of "the ascent of sap in *vegetables* †."

 I. Now,

* Pref. p. 17. 18. † *Ibid.*

I. Now, if the sap ascends in a vegetable, on the same principle that water rises in a capillary tube, of which he seems to have no doubt; let us take a capillary tube, in which, for example, water will be raised to the height of *two inches*. In the tubes of a plant, therefore, whose bores are of the same diameter, the sap should be raised to the same height, but no higher *. On the contrary, I have observed an heavy and viscous juice to issue plentifully at the height of *two feet*; and that out of vessels, considerably larger than the orifice of a capillary tube, within which pure water would not rise to the height of two inches. It is hardly worth while to relate the history of so easy an experiment; however, the plant I made this trial upon, was a very large specimen of the *Tithymalus helioscopius*, or common *sun-spurge*, the trunk of which is without a joint, and was cut transversely near the top of it; after which a section of its vessels was compared, in a microscope, with a section of the glass tube.

II. It

* Dr. Grew has the same remark—"Although we see "that small *glass-pipes*, immersed in water, will give it an ascent for some inches; yet there is a certain *period*, according "ing to the *bore* of the *pipe*, beyond which it will not rise." Anat. of plants, p. 126.

II. It is also to be regarded, that the same quantity of liquor will be *suspended* in a capillary tube when its lower orifice is lifted out of the water, as was raised into it while immersed under the surface. Did the sap ascend into a vegetable on the same principle, it ought to *rest* there, and be *sustained* by the attractive power of the vessels, when the orifices of them are exposed to the open air. The contrary to which appears from experiment: for if a branch of the *birch* be taken off, or a young tree be cut quite away, and held in the same perpendicular posture in which it grew; the vessels will bleed copiously from the bottom, as when a limb is cut off from an animal; and the like will happen in many other plants. Again; water will never run out at the *upper orifice* of a capillary tube, be it ever so short. But the stump of a vine, as Dr. Hales hath shewn us*, will send up its sap into a tube cemented upon it, to the height of 20 feet and upwards. These things being considered, it follows to a demonstration, that the juices are not attracted by a plant, but forcibly compelled into its vessels.

III. In a capillary tube, it makes no dif-

* See Veg. Stat. Exp. xxxix.

ference, whether there is air on the surface of the water into which it is immersed, or whether the air be exhausted; the experiment succeeding equally *in vacuo*. And the same ought to succeed in a vegetable; to which, on the contrary, air is found to be so necessary, that no plant can take up its nourishment, nor will a seed ever germinate so long as the air is absent.

IV. There is no season of the year in which a glass pipe will raise water to a greater height than at another; the effect being just the same in the depth of winter, as in the heat of summer. But the rays of the sun, or the heat of an artificial fire, (which is equivalent,) is so absolutely requisite to the growth of herbs, that, in their season for taking in the sap, in their stature, and in their qualities, they are wholly influenced by the sun's heat all over the world. The plants which are lowest in their stature spring up first; as the little *Aconitum hyemale*, or *winter wolfs-bane*, which is the earliest of all; *arum*, *chelidonium minus*, *violets*, and a tribe of the like sort, which seldom attain to many inches at their utmost growth, and appear very early in the spring. These are succeeded by others of a larger size, till at last the under-shrubs and

and trees put forth in their order; and when the sun is at his greatest exaltation in summer, the whole vegetable creation is in its greatest glory and beauty. Then as the sun declines, this vegetative motion languishes; and the order they observed in putting forth their leaves, flowers, and fruit, is now inverted in their decay. The tallest trees are generally the first that drop their leaves, and the lower follow at a proper distance, till by degrees the smallest shrubs, except the ever-greens, are all stript of their covering; and so continue till the sun at his return puts new life and moisture into their veins. But what is all this to the ascent of water in a capillary tube? To apply that experiment to the appearances in vegetation, is to introduce a principle to give us a *right notion* of every thing, which actually agrees with nothing in the whole subject.

There had been a fairer appearance of some foundation to build upon, had the ascent of the spirits in the tube of a *thermometer* * been assumed

* "If in the morning (saith Dr. Hales) while the sap "was in a rising state, there was a cold wind, with a mix- "ture of sunshine and cloud; when the sun was clouded, the "sap would immediately visibly subside, at the rate of an "inch

assumed as a proper fact to begin with: and yet this, by itself, will fall very far short of the purpose, though it may bring us somewhat nearer to the truth. For, let a tube of this kind be fixed against a wall with a northern aspect; the fluid contained in it will constantly perform like stages with the sap in vegetables. Should it stand uncommonly high for the season, vegetation will be unnaturally forward; of which this last winter* hath afforded us such an example as never occurred within the memory of man; violets, and some other plants, were observed to be in flower before the expiration of *old December*. When the thermometer is very low for the season, vegetation will be at a stand. But generally speaking, as the spring advances, it will be higher every month till the greatest heat of summer; after which, when the trees begin to drop their leaves, the thermometer

"inch in a minute for several inches, if the sun continued so "long clouded: but as soon as the sun-beams broke out "again, the sap would immediately return to its then rising "state, *just as any liquor in a thermometer rises and falls* "*with the alternacies of heat and cold*: whence 'tis pro- "bable, that the plentiful rise of the sap in the vine in the "bleeding season is *effected in the same manner*." Veg, Stat, Exp. 39.

* 1760,

mometer will subside gradually, till it gets to the freezing point; at and about which the motion of the sap in vegetables is at its lowest ebb.

Thus far we should have been right with respect to the *agency*; though, as to the particular circumstances of it, we should fail without some farther directions. But if we leave out the *sun*, and the *celestial elements*, as things supernumerary to the natural world; and set up to explain all the wonders of vegetation, with no better furniture than the imaginary attraction of a glass pipe; we shall generate insuperable difficulties of a new kind, and remove none of the old ones that naturally belong to this branch of philosophy. Thus it will always happen, when we connect together things foreign to one another; and account for an hundred experiments by one that *hath not been accounted for*; which is unfortunately the case with the *capillary tube*. Thus Gilbert, Kepler, and others, accounted for all the great phænomena of the world, from those of the *loadstone*; and for those of the loadstone, *a formæ tantùm actu immateriali, seu incorporeo processu* *. This magnetical philosophy

* *Gilb. de Magnete.*

philosophy was once in great request, but is now wholly disregarded and forgotten.

I might have taken occasion, in this place, to examine the affair of magnetism, and to prove, that the effect of the loadstone is, 1. not owing to any attractive virtue in the substance, but, 2. to the impulseof an æther; and 3. that this æther is no other than elementary fire. But enough hath already been said to establish the conclusion I had in view. It was not my intention, in this treatise, to compose any thing that should look like a system of philosophy; but barely to settle some important *preliminaries*, which may serve as an introduction to the study of nature, and tempt ingenious men to make some farther inquiry upon mechanical principles. I doubt not, but that those who are conversant in physical researches, will be able to confirm what I have said, with many particular articles from their own observation.

CHAP. VII.

The Conclusion from all the foregoing Arguments and Experiments.

IT may be of use now to collect into one view, the evidence that hath been offered; and to consider, at the same time, what, and how much, we have a right to conclude from it.

In the prosecution of this work upon the *mechanism of nature,* I have endeavoured to disprove all that hath been advanced on the other side of the question; and to establish the affirmative, by an induction of so many positive proofs from nature and experiment, as may serve to put it out of all dispute.

1. First, then, it is clear enough that the operations of nature *may be* mechanical; notwithstanding all the objections, arguments, and demonstrations, which have been invented to support a contrary opinion. Some of these objections are no better than naked and unsupported assertions; which prove nothing, but that the authors of them were persuaded of what they asserted. Other objections

jections are drawn from the *difficulty*, which the learned have found, in assigning a mechanical cause for some particular effects; and these difficulties have been improved into absolute impossibilities; as if it were impossible for God to contrive, what it is not easy for man to comprehend. *Cohesion* hath been a great difficulty: *gravity* another difficulty: and if there were five hundred more, would it not be wrong to draw any positive conclusion, from what, by our own confession, we do not understand? The industry and experience of future times, taking all due advantage of some modern discoveries, may make some things clear and easy, which at present are accounted unfathomable. And man, after all his labour in this life, must expect to find many difficulties, and have the mortification to be ignorant of many things. But how preposterous would it be, to begin a system with those articles, concerning which we have no certain knowledge! It would be like the practice of an architect, who should undertake to build a church, and begin with the weather-cock.

As to *arguments*, the most important of all others, and that which most nearly affects the notion of an universal mechanism, is

is the proof of a *vacuum:* not only as the position itself doth necessarily exclude all secondary causes; but as it pretends also to be founded on facts. The barometer sinks when it is carried higher up into the atmosphere: but the argument, commonly deduced from this experiment, proves so much that it proves nothing. For, at this rate, there ought to be a vacuum, where our senses, with the help of some common experiments, assure us there can be no such thing. Fire, which burns and flames beyond the height to which the twilight is extended, will neither burn nor flame in a vacuum. Sound also is transmitted from thence, if accounts attested in the best manner deserve any credit, perhaps more audibly than it would be at an equal distance upon the earth's surface. These observations will not consist with a vacuum: they will only lead us to suspect, that the element of air is but imperfectly understood.

If we go higher up into the heavens, there again we meet with the *phænomena* of *comets;* of the *philosophy* of which bodies, but little more appears to be known, than that they disprove the notion of a celestial vacuum: for they burn, and flame, and send out va-

pours, just as they would do if the *air* were present to them. Sir Isaac Newton hath been beforehand with us in stating this argument; though in opposition to his own opinion upon some other occasions.

From the *resistance* of different mediums, a *demonstration* is supposed to have arisen for the proof of a vacuum, as absolutely necessary to an undecaying motion. A body, it hath been asserted, must *lose* its motion, by *communicating* it to the medium through which it passes: and this supposition is well known to be the foundation of that famous superstructure which hath done so much honour to the geometrical talent of Sir Isaac Newton. It is upon this account only that he will have the celestial spaces to be void of all *sensible matter*; and thence he takes occasion to introduce *attraction* and *projection* as the only possible causes of the planetary motions. Whereas, in fact, a body may preserve an equal pace through any medium; and its resistance shall be no argument to the contrary, if that medium is appointed to act as the immediate *cause* of the motion. Nor is this a bare speculation, depending on such principles as must be committed to the courtesy

courtesy of the reader; for the thing is reducible to practice.

Air is a resisting medium; yet, instead of *retarding* the motion of the *lamp-machine* by its *resistance*, it preserves that motion by its impulse. And if the motion is discontinued at last, this is not owing to any defect or irregularity in the *cause*, but to the imperfection of the *materials*. If the materials, which are acted upon, would but continue in the same state, the motion would be unretarded, so long as air and fire, which are the causes of it, subsist in the world.

In this experiment, the causes are not *artificial* and *violent*, as when a circular motion is given to a stone whirled about in a sling, or to bullets carried about in a box by the revolutions of a *centrifugal-table*, *&c.* but such as are supplied by nature itself, in its regular method of acting; which both *begins* and continues the motion. What is done by nature in one case, may certainly be done in others. The planets themselves may be carried round in their orbits by the same means. The heavens may be filled throughout with an ætherial fluid; not infinitely rarefied, unresisting, and impotent; but dense, and continuous in its parts: for

if such a fluid is contrived, by the great author of nature, to govern and regulate the planetary motions; never let us fear that it will obstruct and retard *the motion which it gives.* From all this we have sufficient reason to conclude, that the operations of nature *may be* mechanical.

2. Nor is it less evident that they really *are* so. In all those experiments, where there can be no reasonable doubt about the explanation, matter is found to act upon other matter, for the producing of the effect; and we are able to trace this in such a variety of instances, that unless the world is governed by opposite and contradictory principles, the same rule must obtain throughout the whole. The body of man, which is the highest piece of machinery in nature, is made to *see*, and *hear*, and *speak*, upon mechanical principles; and it dies without the constant impression of a *material force* upon it from the element of *air.* By the pressure of this air, the mercury is made to rise in the tube of a barometer: hail, snow, and vapours, are formed in the atmospherical regions, by the different temperatures of it: the clouds are sustained by it, and driven about to water the earth: plants grow and are nourished

rished by it: without it, there could be neither sound, voice, nor language; all fires would be extinct; all animals, whether fowls, beasts, or fishes, would perish; and the whole world would languish and decay.

For those effects, where the cause is not so obvious, a more subtile *æther* is provided; the reality of which hath been proved, and many of its operations pointed out by experiment. It is capable of being transfused, as an element, from one parcel of matter to another. On some occasions, it will add a remarkable increase to the weight of bodies. It will enter the pores, and fill the interstitial vacuities of all other substances; and it acts with a force, and a velocity, adequate to all the effects we can desire to ascribe to it. It gives an *elastic* force to *air*, and occupies every space from which the air is exhausted. In electricity, it shews itself to be *light*, and will occasionally burn and consume bodies as *fire*. It is therefore both light and fire: light, as it illuminates, and renders objects visible; fire, as it burns, and consumes what it acts upon. In the fire of lightning, it appears, by plain inference, to consist of the same matter with the rays of the sun; a

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consideration, which, in common with many others, renders it universal to the whole system of the creation.

3. These are the instruments which God hath manifestly ordained, as secondary and subservient to his own power, in the œconomy of the material world: and they are so universally extended, and incorporated with other things, as to be serviceable in the motion of all its particular parts. Some or other, and in many cases each of these, are present to all those effects which have fallen under the observation of philosophers: and there are no other causes to be found; unless we ascribe unintelligible and innate powers to inert matter, thereby making the effect to be the cause of itself; or can suppose, against the dictates of reason and common sense, that God, who hath created these means, hath made it a rule to act without them. Of these, both art and nature receive the benefit in common. What strange things are brought to pass by every ordinary blacksmith, only by the application of fire and air from his forge and his bellows! If he turns these out of his shop, the strength of his hands will do him but little service; and the rest must be left to attractions and repulsions:

repulsions: but iron and brass do not understand the force of such philosophy. What would the chemist do without his furnaces and his refrigeratories? Hence proceed all his separations, sublimations, condensations, fixations, digestions, chrystallizations, and such like. With the help of these natural causes, very few things are too hard for him; but without them, his whole art would be at a stand. The chemist sees this, and confesses it: he cannot but observe the uses of fire and air within the sphere of his laboratory; and is thence naturally led to acknowledge their uses in the greater operations of nature. Hence it comes to pass, that there are very few chemical writings extant, which will not afford some light to a natural philosopher; but, above all others, the writings of Dr. Boerhaave ought to be valued upon this account.

What fruit then can be expected from the labours of any disquisitor, where he neglects these elements, and would banish them, to make way for such causes only as can operate in a vacuum? He must of course deface the chief beauty of nature; which is no-where so conspicuous as in the dependence that is

 established

established between effects and their causes; and must empty the world of its matter and mechanism, only to fill it with difficulties and mysteries. If he destroys the connection between the parts of matter, he must present us with such a picture of nature, as can resemble nothing but the bones of a skeleton, which cannot stir one step upon natural principles; whereas the work of God is worthy of its author, and the frame of nature is a perfect and well-connected body, furnished with all its proper muscles and ligaments. The bones are united, moved, and lifted by the muscles: if an anatomist, in describing the wonders of the human frame, should leave out these, he must suppose the bones to move themselves; after which, he might go on to argue *against* the muscles, as things useless and unnecessary, mere obstacles to the free and easy motion of the bones within their sockets; and then he would philosophize just as they do, who forget that fluid matter of the heavens, by which all other things are moved and connected together, and place occult powers in the solid matter of the celestial orbs.

To avoid falling into any errors of this kind,

kind, I have taken care to feign no arbitrary and abstracted idea of nature; but have examined it wholly as a matter of fact, and have hitherto argued from observation only, in order to make such a sketch of its out-lines as shall be like the original. And a strong likeness hath often been hit by a very indifferent painter; while some finished pieces, which have shewn a masterly hand, might as well have passed for the figures of some fictitious characters in a romance, as for the persons who sat for them. With regard to my own reputation as a writer, I am perfectly easy; for it was neither my design, nor my desire, to exhibit a pattern of eloquence; but to add some little matter to the common stock of useful knowledge. It is in this light only, that I could wish to have my labours accepted. As to the author himself, the learned, I hope, will find no reason to look upon him as one who would dictate to those who are better able to instruct him, or to impose a belief of any thing which is not supported by plain argument and undeniable evidence. If they do him justice, they will regard him only as a fellow-inquirer after that truth which they also

are desirous to find; and will attend to him as to one who takes great delight in the works of God, and but little in any work of his own.

END OF THE THIRD BOOK.

BOOK IV.

The Judgment of Antiquity on the System of Nature: together with the Sentiments of some Modern Authors of the best repute.

CHAP. I.

Some General Observations *on the* Learning *of the* Ancients.

TO what hath already been deduced from observation and experiment, let us now try if we can add the sanction of some clear and indisputable testimonies from antiquity. This inquiry will be useful and pleasant in itself; and the result of it, I hope, will be satisfactory, as it may serve to repel any charge of *novelty*, which, if it were well-grounded, might be urged with some success against the doctrine of the *mechanism* of the world, and the influence of *material*

causes,

causes. For, as I have pretended that these things are equally *plain* and *important*, there could be no better objection against them as such, than that mankind should have been left to this day in ignorance of them.

For my own part, I have always been persuaded, that, in our judgment of physics, a proper regard ought to be paid to the concurrent testimonies of ancient writers; who had, in many respects, the same opportunities that we have, and made it their practice to derive their knowledge of things from evidence and observation. How far they were able to carry their observations, it would be difficult to shew with any tolerable precision; farther, I think, than they are allowed to have done by the general stream of modern writers; some of whom are weak enough to believe, that wisdom is a child newly born, though the world is now in its dotage.

Thus much, however, is certain and indisputable, that there are innumerable appearances and operations in nature, which are subjected to the eyes and senses of men, though unassisted with some inventions of art, which are usually reckoned peculiar to the latter ages; and as nature is consistent with

with itself, from these such a judgment might be formed concerning the whole, as should be subject to no material errors, though it might fall short of a mathematical exactness.

The skill of the ancients, in mechanical arts, is generally confessed to have been very great; and there are some such monuments of it still remaining, both great and small, as their sons at this day would find it hard to exceed, or even to imitate. And it is well known, that, in three branches of science, very nearly allied to natural philosophy, their attainments are the foundation of modern learning. Their *geometry* and *mathematics* ought to be remembered first upon this occasion; the principles of which are derived from the writings of Archimedes, Euclid, Apollonius, and some other authors. And many of the most valuable parts of mathematical learning seem to have been more ancient than the names of the writers to whom they are ascribed. The Greeks were always notorious for pretending to invent, what, it is evident, they were at the pains to glean up among nations more ancient and wiser than themselves. The story of Pythagoras sacrificing an Hecatomb, when he had

found out the forty-seventh proposition of the *First Book* of Euclid, looks very suspicious, and hangs so badly together, that the whole seems rather to have been a fiction. For, how could that philosopher sacrifice an *hundred oxen*, who made it a point of conscience never to sacrifice any living creature? It is more probable that his *geometry* was imported, together with his *astronomy*, from the Egyptians*, among whom he had travelled in search of wisdom and learning.

But it is a matter of no concern to the present argument who were the inventors; thus much being certain, that the ancients were actually in possession of all the most considerable and useful parts of the mathematical sciences. It hath been suspected, from

* Πυθαγοραν τε τα κατα τον ιερον λογον, και τα κατα γεωμετριαν θεωρηματα, και τα περι τες αριθμες, ετι δε την εις παν ζωον της ψυχης μεταβολην, μαθειν παρ' Αιγυπτιων. *Pythagoras learnt from the Egyptians his knowledge of hieroglyphics or symbols, his* geometrical theorems, *his mysteries and powers of numbers, and also his doctrine of the transmigration of souls.*—This is part of a famous passage in the first book of Diodorus Siculus, wherein that historian confesses, that the Greeks borrowed both their philosophy and mysteries from the Egyptians. It is quoted by Eusebius, Præp. Evang. l. 10. and is printed at the end of the works of Clemens Alexandrinus.

from some idle expressions among the poets, that the ancients judged the earth to be a *flat surface*, and that the sun every evening went hissing into the western ocean. Whereas it is known to those who inquire farther, that their mathematicians always held the earth to be a *sphere*, as we do now; and some of them, from the earliest times of which we have any account, endeavoured to find out the measure of a degree upon its surface*, by the meridian altitudes of stars near the zenith; a problem, in the solving of which the French aſtronomers laboured so much some years ago.

Then again, as to their knowledge of *physic*; how venerable are the names of Hippocrates, Aretæus, Celsus and Galen! and, what is worthy of observation, the author, who is the most ancient of these, is deservedly the best reputed. Where the moderns take advantage of these writings, and form their judgment after the model of antiquity, it is always found to answer: and a physician of good

* This hath very lately been taken notice of in Mr. Stone's supplement to his new edition of Bion's book on the *construction and uses of mathematical instruments*, p. 318; a treatise that ought to be in the hands of all lovers of mechanical and mathematical arts.

good abilities, who takes this course, is sure to do honour to that profession, which of all others is one of the most honourable.

The modern anatomy is chiefly distinguished from the ancient, by a knowledge of the circulation of the blood: and yet there are passages in some ancient writers, which seem so nearly to describe it, though indeed with no great accuracy of expression, that I confess I am not anatomist enough to see fully where the difference lies. They appear to have known, that the blood is thrown into the heart by the *vena cava*, and is distributed again, from the same fountain, to all the different parts of the body *. Whether they did actually infer, that it returned again to the heart through some capillary inosculations

* Lapsus cibus—in eam venam, quæ cava appellatur, confunditur, *perque eam ad cor* confectus jam coctusque perlabitur: *a corde autem in totum corpus distribuitur.* Cic. de Nat. Deor. lib. 2. cap. 55.

In corde—quatuor orificia, bina in utroque ventriculo: alterum quidem inducit, alterum vero educit—per alterum *sanguis trahitur*, per alterum *emittitur*. Galen. de usu. part. l. 6.

It is observable, that Plato, in his Timæus, as quoted by Longinus, styles the heart πηγὴν τȣ ΠΕΡΙΦΕΡΟΜΕΝΟΥ σφοδρως αἱματος. Long. p. 170. edit. Pearce.

tions of the veins and arteries*, may indeed be questioned; and I would leave this to be determined by the physicians, whose reading is more extensive, and whose proper province it is to judge of such things.

But

* That the blood hath such a circulation as this, especially in the *lungs*, seems to be affirmed by Galen in the following words, which I would desire the learned reader to consider: they are quoted by Harvey, Exercit. anat. 1. cap. 7. *In toto est mutua anastomosis* (inosculatio) *atque osculorum apertio arteriis simul cum venis; transumuntque ex sese pariter sanguinem & spiritum, per* invisibiles *quasdam atque angustas plane vias, &c.* That Galen knew the *arteries* to be filled with *blood* as well as the veins, is clear from his own experiments. "Hippocrates" (says Dr. Boerhaave) "has had the honour given him of knowing the "circulation, first by Riolan, and then by Drelincourt "and others; but it is certain, that if he understood the "blood's motion, he has expressed himself so unintelligibly "about it, that his acutest interpreter, Galen, did not "thence so much as suspect that the blood had a circulating "course," &c. See Dr. Boerh. *Academical Lectures*, vol. 2. p. 38. of the English translation.—Thus far we must agree with this learned author, that if the ancients had a knowledge of the circulation, their expressions upon the subject are at least defective, if not unintelligible. And it hath happened, in many instances, that the truth hath never been sufficiently cleared up and established, until it hath been expressly disputed. Certain it is, that the Galenists did absolutely deny a circulation: in opposition to whose system, the truth was either restored or discovered by the solid reasonings and experiments of Harvey.

But when I speak of the wisdom of the ancients, it is chiefly with a view to their knowledge of *Astronomy*: for, although it may be doubted, to what original we ought to refer the whole merit of the invention, it is clear enough, that the true *solar system*, revived by Copernicus, and confirmed afterwards by the telescopes of Galilæo, was well known to the astronomers of antiquity, who obtained it from Egypt and Phœnicia.

I cannot help observing, upon this occasion, what a mischievous thing *authority* is, when it hath once gained a footing among those who search after the knowledge of nature. The name of Aristotle, and the example of king Ptolemy, gave a currency to a most unnatural and absurd system, and kept the world for many hundred years in a state of darkness, from which it was recovered at last, not without great difficulty and violent opposition. There was a pleasant instance of a philosopher at Florence, whose prejudices had taken so deep root, that he could never be persuaded to look through one of Galilæo's telescopes, lest he should see something in the heavens that might disturb him in his belief of Aristotle's philosophy.

This same Aristotle informs us, that an astronomical system, contrary to his own, was maintained by those of the Italic sect, who were called Pythagoreans: for these, says he, assert that fire is in the midst of the world, and that the earth, moving as one of the stars, performs a circuit round this centre, by means of which the changes of day and night are brought to pass. And the same author adds, that many others beside the Pythagoreans judged it improper to place the earth in the centre of the world *.

Archimedes delivers it as the opinion and doctrine of Aristarchus Samius, that "all "the fixt stars and the sun are without mo- "tion: that the earth is carried round the "sun in the circumference of a circle, of "which the sun itself is the centre: and "that the sphere of the fixt stars is so im- "mense, that the circle of the earth's an- "nual orb bears no greater proportion to it,

* Εναντιως οι περι την Ιταλιαν καλουμενοι δε Πυθαγορειοι λεγουσιν. Επι μεν γαρ του μεσȣ πυρ ειναι φασιν, την δε γην εν των αστρων ουσαν κυκλω φερομενην περι το μεσον νυκτα τε και ημεραν ποιειν—Πολλοις δ᾽αν και ετεροις συνδοξειε μη δειν τη γη την τȣ μεσου χωραν αποδιδοναι. Arist. de Cœlo, l. 2. c. 13.

"than the centre of any sphere bears to its "whole surface*."

Laertius and Stobæus ascribe the same doctrine to Philolaus. By the latter of these we are informed, that he "placed fire in the "middle of the world, at the centre, and "called it the *focus* or *hearth* of the uni- "verse †." From this philosopher, Plato is reported to have borrowed much of his knowledge; and, according to Plutarch, he repented toward the latter end of his life that he had not followed him in this article also.

Lastly, Seneca mentions it as a question worthy of contemplation, "whether the uni- "verse revolves, the earth being at rest; or "whether the earth moves, while the uni- "verse is fixed? For *it hath been maintained* "*by some*, that we, the inhabitants of the "earth, are carried about by an imperceptible "motion; and that the rising and setting "of

* Archim. Arenar. lib. 1.

† Φιλολαος πυρ εν μεσω περι το κεντρον, υπερ εστιαν, τȣ παντος καλει. Stob. περι ταξ. τȣ κοσμȣ.

In his chapter περι ουσιας αστρων, &c. he observes of the mathematicians, that some followed Plato; while *others asserted the sun to be in the middle of the world*—φασιν μεσον παντων τον ηλιον.

"of the stars is not occasioned by a motion "of the heavens, but that we ourselves rise "and set here upon the earth*."

The ancients therefore were acquainted with the disposition of the world according to the true solar system: and there is little doubt but that the Ptolemaic hypothesis was novel in comparison of it; a scheme rather adapted to the prejudices of sense, and the corrupt philosophy of Aristotle, than established in the world for any intrinsic merit of its own, or any rational conformity with nature itself. How plain and natural does the Copernican system appear, now the industry of man hath been sufficiently employed upon it! and how easily might it have been retrieved much earlier, if astronomers had not given up their understandings to what they never were able to make any sense of! Men are always jealous enough of their bodily liberties, and are too often ready to claim a right of judging and contradicting, where they ought to be obedient; while they tamely

* Utrum mundus terrâ stante circumeat, an mundo stante *terra vertatur*. Fuerunt enim qui dicerent, nos esse, quòs rerum natura nescientes ferat, nec cœli motu fieri ortus & occasus, sed ipsos oriri & occidere, &c. Nat. Quæst. lib. 7. c. 2.

give up the liberty of the understanding to those who have no right to demand it, as Aristotle certainly had not. And yet his very name did once convey an idea of all that is great and wise, to those who followed like a swarm of bees, and would shew an invincible affection, even for a dry unfruitful stump of a tree, if their leader happened to light upon it. It was owing to that idle uninquiring spirit, which possesses most men, that the nations conquered by his pupil Alexander, were less numerous, and less submissive, than the subjects of Aristotle; in the days of whose dominion, common sense was in a manner buried and overwhelmed by a verbose wisdom, which employed itself only in distinguishing, subdividing, and disputing about its present stock of matter; not in the making of such experiments, as might have corrected what was amiss, and supplied what was wanting; because the attempt would have derogated from the praises of Aristotle.

The memory of Nicolaus Copernicus will always deserve to be regarded, in that he was the first who dared openly to set a better scheme on foot, in opposition to the furious prejudices of the age he lived in: and it is the

the greatest praise of Descartes, that his labours, for a time, gave a finishing stroke to the tyranny of scholastic learning. The divine providence itself seems to have favoured and seconded the attempt of Copernicus, in raising up Galilæo, to demonstrate, by his telescopes, some articles not very easy of digestion, which Copernicus could only assert upon principle, without being able to confirm what he said by such sensible proofs as the cause seemed to require. And Galilæo himself had piety enough to ascribe this sudden and wonderful turn of things to that supreme power*, by whose direction all useful discoveries and improvements of science are made to arise, at those times and seasons when his wisdom sees them to be most expedient: though, perhaps, in strictness of truth, it may be more proper to term these *restorations of science*, than original discoveries. And the farther I inquire, the more I am tempted to believe, that, even in this sense, *nihil est sub sole novi.*

These things are worth considering before we enter upon the succeeding chapters: for there must needs be a fair prospect of

U 3 finding

* —Ope perspicilli a me excogitati, *divinâ prius illuminante gratiâ.* Galil. *Syder. Nunc.* p. 10.

finding some very discernible footsteps of a true philosophy among those writers, from whom the true astronomy, after many ages, was so happily recovered. And, in fact, we shall find them declaring so expressly, and almost unanimously, for the principles I have endeavoured to deduce and justify from observation, that, if I had been allowed to invent such expressions as should agree best with my own sentiments, they would have been just such as I am able to produce. Some examples of this I have already given in the foregoing part of this work, by throwing a few passages occasionally into the margin. I ought indeed to make some apology for setting out to view so many Greek and Latin quotations, in a treatise written in English. But how is it possible for me to avoid it? for we cannot have the sentiments of the ancients without their languages; of which, however, I shall disturb the text of my book with as little as possible.

CHAP.

CHAP. II.

Testimonies from the principal Authors of Profane Antiquity among the Greeks.

PLATO, who was the head and founder of the *Academics*, and without exception the greatest and most amiable philosopher among the *Greeks*, whose sentiments also, in regard to natural philosophy, are supposed to have been the same with those of Pythagoras*, denies a *vacuum* upon all occasions, and asserts in general, that "fire and heat beget and "GOVERN all other things†." Where he descends to particulars, as in the dialogue that bears the name of Timæus, he accounts for the animal functions from an *intertexture of air and fire*‡ acting throughout the whole frame of the body. To *fire* he ascribes the

* Plato is reported to have borrowed the doctrines in his Timæus, from the writings of Philolaus, a scholar of Pythagoras. These writings (as Hermippus relates) he purchased at the extravagant price of 40 Alexandrian minæ of silver.

† Το γαρ θερμον τε και πυρ ο δη και τ' αλλα γεννα και επιτροπευει. Theætet.

‡ Πλεγμα εξ αερος και πυρος.

the office of *expanding within*, and acting through the body outwards; while the element of *air compresses from without*, and counteracts the force of the internal fire. *By the ministry of these causes* *, and the impossibility of a *vacuum*, a *perpetual circulation*, as it were †, is kept up, through the motion of the lungs in inspiration and respiration. The effects observable in *gravitating* and *projected* bodies, as also in *amber* and the *loadstone*, he imputes to the action of the same elements, and supposes them to be brought to pass after a manner analogous to that above mentioned: for, in all these cases, he observes, *there is really no such thing as an attraction* ‡; but the *causes* already assigned will be found, *by those who inquire diligently*, to effect all these wonders of nature by their *reciprocal impulses*.

In another part of the same dialogue, speaking of the manner in which vision is performed, by the mediation of elementary fire and light, he says, "These are the *secon-*"*dary*

* Αις χρωμενον ΑΙΤΙΑΙΣ.

† Τουτο παν οιον τροχου περιαγομενου γινεται.

‡ Παντων τουτων ΟΛΚΗ μεν ουκ εστιν ουδενι ποτε.

N. B. This passage may be consulted at large, as well in the *Eclogæ Physicæ* of Stobæus, as in the works of Plato himself.

"*dary and co-operating causes* which *God* "makes use of as *his ministers*, for the finish- "ing and perfecting of his work. Most "men look upon these, not as the *secondary*, "but as the *primary causes of all things*, in- "asmuch as they occasion *heat* and *cold*, can "effect the *cohesion* and *dissolution* of bo- "dies, and perform all other things of this "kind *." This passage, while it suits my purpose, and shews how deep Plato was in the mechanism of nature, is superior and contrary to the opinion of this author himself on some other occasions †, and supplies us with a valuable testimony against the idolatry of the heathen world in general, who exalted the creature into the place of the Creator. I know not how to account for this sentiment from the mouth of Plato, unless it be taken for one of those many articles, which this great philosopher, to use the words of Serranus—*aliundè ex meliore doctriná acceperat.*

Cicero, speaking of the ancient Platonists, relates

* Ταυτ' ουν παντ' εστι των ξυναιτιων, οις Θεος υπηρετουσι χρηται, την του αριστου κατα το δυνατον ιδεαν αποτελων. Δοξαζεται δ' υπο των πλειστων ου ξυναιτια αλλ' αιτια ειναι των παντων, ψυχοντα και θερμαινοντα, πηγνυντα τε και διαχεοντα, και οσα τοιαυτα απεργαζομενα.

† For the truth of this reflexion, consult Cicero de Nat, Deor. lib. 2. c. 12.

relates in few words how they treated the subject of natural philosophy. "They divided nature into two parts, one of which was *active*, the other *passive*. They held it impossible for bodies to *cohere*, unless they were kept together by some force; and that it was necessary this force should be exerted by *some matter*. In distinguishing the several uses of the elements, they attributed to air and fire the power of giving motion and causing effects; to earth and water a passiveness, or disposition to receive their impressions *." Cicero seems here to have borrowed his sense from some passages in Ocellus Lucanus, a Greek author of great antiquity, who was a disciple of Pythagoras. He reduces all the different parts of the universe to what he calls "*generation*, and the *cause of generation*; the latter of which, as observation teaches, hath the power of moving and effecting; while it is the office of the former to be "passive,

* De naturâ autem ita dicebant, ut eam dividerent in *res duas*: ut altera esset *efficiens*, altera autem quasi *huic se præbens*—neque enim materiam ipsam cohærere potuisse, si nulla vi contineretur; neque vim sine aliquâ materiâ. —Illa initia elementa dicuntur; e quibus *aer* & *ignis* movendi vim habent & *efficiendi*, reliquæ partes *accipiendi* & quasi *patiendi*, aquam dico & terram. Acad. Quæst. lib. 1.

"passive, and receive motion. Heat and "cold, which (according to his own inter- "pretation) are the *δυναμεις* or *faculties* of "fire and air, are the causes and efficients; "the dryness and moisture of the earth and "water afford them materials to work "upon *." And this agrees with what Hermias, the christian philosopher, gives us as the opinion of Pherecydes the Syrian, who drew his learning from the books of the Phœnicians, and is reported to have been the teacher of Pythagoras, that "*æther is the agent,* "*earth the patient* †."

Zeno, who was the leader of the *Stoics*, taught, that "nature is supported by an ele- "mentary fire diffused through all the parts "of it ‡: that there is no vacuity, the world "being so completely united in itself, that "there is a connexion and harmony between "things celestial and terrestrial §.

This

* Φανερον οτι περι μεν την αιτιαν της γενησεως το ποιειν και κινειν εστι. Περι δε το δεχομενον την γενεσιν το πασχειν και το κινεισθαι. Ocell. Lucan, cap. 2. Το μεν θερμον και ψυχρον ως αιτια και ποιητικα: το δε ξηρον και υγρον ως υλη και παθητικα. Ibid.

† Ο μεν αιθερ το ποιεν, η δε γη το πασχον. Bochart. Geogr. Sacr. p. 236.

‡ Cic. de Nat. Deor. lib. 2.

§ Diog. Laert. Zeno.

This mechanical connexion between the distant parts of the universe, was ingeniously expressed in a figure of the great Diana of the Ephesians, still preserved upon some ancient coins*. This idol, the same with the Egyptian Isis†, was plainly intended to represent the whole system of nature. Her body is closely wrapt up and concealed from the head to the feet, under a variety of hieroglyphical ornaments, to signify the *first matter* of the universe hidden beneath the external *forms* and figures of things. (See plate III. fig. 3. page 196.) In her open face is the splendor of the day; her veil behind shews the darkness of the night; her multitude of breasts, the fertility of the earth, which, as a fruitful mother, suckles and supports all her productions: her hands spread out, express the efficient power or agency of the superior elements; and to shew that these act only by means of mechanical impulses, and a connexion with even the most extreme or lowest parts of nature, a *chain* is carried down from each hand of the image, and connected with its feet. The sense

* See Menetrii Symbol. Dian. Ephes. p. 10.

† Την δε της Ισιδος (τελετην) τη της Δημητρος ομοιοτατην υπαρχειν. Diod. Sic. ubi supra.

sense and meaning of this chain may be well expressed in the following words of a critical author of great learning —*In mundo ratione nullâ esse potest vacuum—etenim nisi nexibus mutuis colligaretur universitas, nec mundum natura contineret nec regeret, nec partium invicem ulla foret societas**. The *golden chain*, let down from heaven to earth by Jupiter, requires the same interpretation; for Plato hath observed, that by this chain Homer meant to speak of the *sun*, that is, of the power and influence of the sun upon terrestrial things†.

If the sun really does act upon bodies at a distance from him, it must be by means of such a chain of matter. It was upon this consideration that Vossius rejected the opinion of those "who supposed the *æther* to "be nothing but a great void, in which the "stars

* Cæl. Rhodigin. lib. i. c. 7.

† Την χρυσην σειραν ως ουδεν αλλο η τον ηλιον Ομηρος λεγει. Theætet. See also Macrobius in Somn. Scip. lib. 1. But Pierius has an observation more to the purpose than any I have met with.—*Juno catenâ de cælo ab Jove suspensa, & lapides pedibus alligatos habens, ab* Homero *fingitur; ita ut unum pedem contractiorem habeat altero. Quæ imago quatuor elementorum symbolum est. Juno enim ipsa aerem significat*: catena ignem, *quo cætera* colligantur, &c. Pier. Hieroglyphica. lib. LIX.

"stars performed their courses: than which "(as the same author observes) nothing can "be more contrary to reason. For it is ne- "cessary the heavens should be of a corpo- "real substance, that they may act upon in- "ferior things; which cannot be without "either immediate contact, or the interven- "tion of some substance extended from the "one to the other. Hence the system of "the world must be continuous in its parts, "or at least contiguous, that things above "may communicate their light and heat to "things below *." So agreeable is this both to reason and observation, that some writers, who, in all appearance, sat down with a resolution to maintain a *vacuum*, have at times yielded to the remonstrances of common sense, and relapsed into this doctrine of Vossius, though in direct opposition to their own

* Multorum ea foret opinio, quod æthera dicimus, nihil aliud esse, quam magnum inane, per quod sidera suum conficerent cursum. Quos interea nimium quantum ratio fugit. Nam necesse fuit cœlum corporeæ esse substantiæ—ut sidera agere possent in inferiora, quod fieri non poterat sine contactu, sive is per se foret, & sine corporis alterius interventu, sive per aliquod fieret intermedium. Ut necesse sit, omnia vel continua esse vel contigua saltem, quo superiora possint inferioribus impertire lumen ac calorem suum. Voss. de Orig. & Progr. Idol. lib. 2. p. 255.

own principles. We had an instance of this in Book 2. chap. 3. But let us proceed with our inquiry.

After the *Academics* and the *Stoics*, the *Peripatetics* were most considerable. Aristotle, their founder, though mistaken in some things, was wise enough to concur with the best philosophers of antiquity in disbelieving and rejecting a *vacuum*. He attributed to nature an universal *abhorrence of a vacuum*, and accounted for many effects upon this principle, the merit and meaning of which it is not worth while to enlarge upon in this place. Against those who insisted on a vacuum as necessary to motion, he rightly argued, that "a plenum is capable of being so affected, as to consist very well "with the motion of bodies in it: for its "parts may yield mutually to one another, "and give an easy passage to bodies, though "the space in which they move is full of "matter. Of this, (he tells us) we have "an instance in the *circumgyrations* of *continuous* bodies, and also of *fluids*. Nor "does it follow that there is a vacuum, because some masses of matter may be compressed into lesser dimensions; for if water "should be forced into a smaller space, the

"air it contains would be forced out of "it*." Aristotle might have added, that if air is compressed, the fire is forced out of it; the same rule being observed in all cases of this nature.

It is very probable, that Descartes might take an hint from this passage, to obviate that imaginary necessity for a vacuum, with which he was occasionally pressed by some learned men of his own time. He supposes a number of solid spheres to be disposed in the form of a circle, and all of them in contact. One of these spheres cannot be moved forward in the circle, without moving all the rest; so that the place of the sphere first moved shall be instantaneously supplied by that next behind it: and thus the motion may be continued, though there is absolutely no void interval between any of the spheres †. We have an example of this, when we gave a circular motion to water or mercury

* Αλλοιεσθαι γαρ ενδεχεται το πληρες· αλλα δε ουδε την κατα τοπον κινησιν· αμα γαρ υπεξιεναι αλληλοις ενδεχεται, ουδενος οντος διαστηματος χωριστου παρα τα σωματα τα κινουμενα. Και τουτο δηλον και εν ταις των συνεχων δινais, ωσπερ και εν ταις των υγρων. Ενδεχεται δε και πυκνουσθαι μη εις το κενον, αλλα δια τα ενοντα εκπυρηνιζειν, &c. Aristot. Phys. lib. 4. c. 7.

† Du Hamel de consensu Vet. & Nov. Phil. p. 128.

cury contained in a cylindrical vessel: the parts, though in motion, will still preserve their connection, and will occupy no more space than when they were at rest. The motion we are now speaking of, being *vortical*, yielded an illustration most agreeable to the physical plan of Descartes: but a motion in the several parts of a plenum, is by no means limited to the form of a *vortex*; for, when a liquor is *fermenting*, an intestine motion is generated among its parts in all directions, which will continue for some days; and if the liquor is set to ferment in a transparent vessel of glass, the sight is very curious. How very ill the continuance of such a motion agrees with the vulgar inference from the *theory of resistance*, I leave the mathematicians to consider.

From Aristotle let us go next to Hippocrates, a man almost deified for his knowledge, by those of his own times, though he was not the master of any particular sect of philosophers. He had enriched his mind from the experience of earlier times, and derived a considerable part of his own skill from a diligent study of nature. His opinion, in general, may be learnt from the following passage: "The element of *air* has a dominion

" over the human body, and is the principal " source of all things that happen to it, " whether good or bad. Its power and in- " fluence deserve well to be accurately ex- " amined; for wind is no other than a cur- " rent of air rolling along in impetuous " waves, which are so violent as to tear up " trees by the roots, raise the waters of the " ocean into a storm, and overwhelm and " sink the largest vessels to the bottom " of the deep: such and so great is the " power it exercises, though at the same " time it is not an object of our sight, but " manifest only to our reason. What are " the effects to which air is not necessary? " or in what place is it not present? All the " space between the heaven and the earth " is filled with it. It is the cause both of " the winter and the summer. In the winter, " it is condensed and cold; and in the " summer, it is mild and serene. The sun, " moon and stars are directed by it in their " courses; for air is the aliment of fire, and " fire that is deprived of it becomes extinct: " so that the sun itself has a perpetual mo- " tion by means of a pure and perennial " air. The sea itself is impregnated with " this element, because the inhabitants of

" the

"the water cannot subsist without it: in a "word, it sustains the moon in its orbit, "serves as a *vehicle* * to the earth, and no "place is void of it †."

This author having ascribed so much to the air, you may suspect, perhaps, that he has left no room for any other physical agent. He speaks, however, as explicitly in other places of an universal *fire;* and particularly in his book *de diæta,* wherein he affirms, that this element "disposes all things in the

 "body

* Οχημα, which is the word here, being rarely used for any thing but a carriage *moving* by land or water, for all the kinds of which it is a general term, (as see Jul. Pol. Onomast. lib. 1. c. 9. lib. 10. c. 12.) should imply a *motion* in the earth: but I know not how to reconcile this with what goes before, concerning the δρομος ηλιȣ, or *course of the sun,* unless we suppose Hippocrates to have alluded, not to the motion of the sun's body, but the emission of his *light,* to which the word ηλιος hath sometimes been applied. Thus in Mimnermus περι βιȣ it is said—οσον τ' επι γην κιδναται ηέλιος; *quamdiu super terram* spargitur *sol?* which must signify the *light* of the sun, as surely as Homer meant the *light* of the morning, where he says—Ηως μεν κροκοπεπλος εκιδναλο πασαν επ' αιαν. And Sallust, the Greek philosopher, observes yet more expressly—Του ηλιȣ την σφαιραν, και την απο της σφαιρας ακτινα ΗΛΙΟΝ εν συνηθεια καλουμεν. De Diis & mund. cap. 4.

† Ουλος δε (αηρ) μεγιστος εστιν εν απασι των συμπλωματων δυναστης—— to —κενεον δε ουδεν εστιν τȣτου. Hippoc. de flatibus, p. 1.

"body after a manner proper to itself, and "according to the similitude of the universe, "so that small things are like to great, and "great to small: that it is most powerful, "hath an universal dominion, and governs "all things according to the order of na- "ture; while itself is silent, invisible, im- "perceptible in its operations, and in per- "petual agitation *."

Thus far we have followed Hippocrates as a naturalist. If we consult him as a theologist, he will tell us, that this *fire* is divine and intelligent, endued with mind, reason, and wisdom †, and to be understood as the fountain of these to all other beings! He confesses himself to have believed, that what is called *heat*, is immortal and omniscient, capable of hearing and seeing, and acquainted with all things both present and to come. This, he adds, is what the ancients understood by *æther* ‡. He speaks of the

air

* Παντα διεκοσμησατο κατα τροπον αυτω εαυτο τα εν σωματι το ΠΥΡ, απο μιμησιν του Ολου, μικρα προς μεγαλα, και μεγαλα προς μικρα.——Ισχυροτατον πυρ, οπερ παντων επικρατεεται, διεπον απαντα κατα φυσιν· αψοφον και οψει και ψαυσει——ουδεκοτε ατρεμιζον. Hippoc. de Diæta. p. 11.

† Εν τουτο ψυχη νοος φρονησις. Ibid.

‡ Νυν δε αποφαινομαι αυτος εμεαυτου γνωμας· δοκει δε μοι

ο κα-

air in the same strain, as endued with *mind* and *understanding*, giving *sense* to the brain as well as motion to the limbs *.

This doctrine opens to us the whole secret of the pagan idolatry. The philosophers of the heathen world were well acquainted with the influence of these elements over all other things: and being ignorant of the true and living God, judged it to be impossible that air and fire could perform such wonders unless they were divine, and therefore worshipped them universally as immortal and intelligent. This is the error which *Plato*, having by some means obtained a better light, so clearly condemns, in that memorable passage, where he speaks of physical causes: But it was an error so deeply rooted, that this sublime philosopher himself was not altogether free from it.

Phurnutus the mythologist confesses plain-

ο καλεομενον θερμον αθανατον ειναι, και νοειν παντα, και ορην και ακουειν· και ειδεναι παντα τα οντα και μελλοντα εσεσθαι——ονομηναι μοι αυτο δοκεουσιν οι Παλαιοι αιθερα. Hippoc, de carnibus. p. 1.

* Αηρ—εισιων ες τον εγκεφαλον—την φρονησιν και την κινησιν τοισι μελεσι παρεχει. De morbo sacro, p. 89. ες το σωμα σκιδναται ο αηρ, καταλιπων εν τω εγκεφαλω εαυτου την ακμην, και οτι αν εῃ φρονιμον τε και γνωμην εχον. Ibid. p. 93.

ly enough, that the Jupiter and Juno of the Greeks were *fire* and *air* *. The former he describes as the *soul of the world*, and imagines the human soul to consist of the same substance. Their εκατηϐολος Apollo, in the utmost sublimity of its meaning, did certainly express nothing higher than the *light* of the sun; as it is evident from all the epithets and attributes ascribed to this deity by the ancient poets and mythologists. Macrobius, with a great compass of learning, and as great an appearance of truth, reduces all the gods of the Gentiles to the various effects and operations of the *sun*. If the reader should have any desire to be farther acquainted with these things, I would recommend to his perusal the Treatise of Phurnutus upon the *nature of the gods*, and a part in the first book of the Saturnalia of Macrobius, from the beginning of the *seventeenth*

* See the 2d and 3d chapters of his book *de Natura Deorum*—*Ignis* enim, id est *Jupiter*, &c. Fulgent. Mythol. lib. III. c. 7.—*Juno* posita est in similitudinem *aeris*. Antiqui enim ipsam *Jovis*, id est *Ignis*, uxorem & sororem dixerunt. Albricus de Deor. Imag. cap. xi.

Tum *Pater omnipotens* fœcundis imbribus ÆTHER
Conjugis in gremium lætæ descendit, & omnes
Magnus alit magno permistus corpore fœtus.

Virg. Georg. lib. II. 326.

teenth to the end of the *twenty-third* chapter: from all of which, he cannot easily fail of imbibing some taste for the heathen *mythology*; a branch of the ancient learning, very curious in itself, and not without its usefulness, when it falls into proper hands.

As the Greeks borrowed both their learning and their religion from the Egyptians, it is highly probable that the philosophy and theology of that ancient people must have coincided, even from the earliest times, with these placits of the Grecian sages. And this is confirmed by the most early account we have of the Egyptians, in the sacred writings. For the *miracles* in Egypt seem to have been chiefly calculated to assert an over-ruling power of the true God, and distinguish it from the above-mentioned philosophical objects of the heathen worship, which were no other nor better than the works of his hands, though ignorantly and profanely dignified with the exalted attributes of omniscience and eternity. The *Lord* is said to have executed judgments upon the *gods of Egypt* *; which I cannot but suppose to have happened, when their

* Numb. 33. 4. See also Exod. 18. 11. which is very express.

light was turned into darkness; the *wind* brought locusts, and scattered the ashes of the furnace over the whole land; the heavens sent down a storm and tempest upon them, and fire ran along upon the ground, devouring and laying waste the fruits of the earth.

These elements they worshipped, not, according to Plato's excellent distinction, as *secondary instruments* in the hands of God, but as the primary causes of all things, and the supreme governors of the world, denying and rejecting the supremacy of that God of the Hebrews, who created the world in the beginning, does now sustain the powers of nature, and will at last overthrow what they vainly believed to be immutable and eternal. It does not fall in with my design to say any thing of the other miracles; though they may easily be accounted for from some circumstances in the history; whence it will appear, to those who consider the case attentively, that this cruel and oppressive people were *punished* by the very things wherein they had *offended;* as it was observed long ago by the author of the apocryphal book intitled *The Wisdom of Solomon* *.

The

* See chap. 11. v. 6. 7. 16.

The philosophy of the more modern Egyptians is hardly to be collected from any express testimonies, involved as it is under the obscurity of emblems and hieroglyphics; which those who have undertaken to explain, as Horapollo, Pierius, Kircher, and others, appear to have understood but very imperfectly. The safest way, therefore, is to collect the general intention of it, from what the most early philosophers of Greece borrowed from them: the substance of which we have seen already.

CHAP. III.

Some Observations on the Remains of the Chaldaic *Philosophy.*

OF the Chaldaic philosophy there is little remaining, but a few fragments and mutilated passages; in which, however, there are some valuable hints, from whence a tolerable idea of it may be collected.

In the oracles of Zoroaster *, mention is made

* Inserted in Stanley's Lives of the Philosophers, from Franciscus Patricius.

made of an harmony or *melody of the* æther, *of the* sun, *of the* moon, *and of all things that are surrounded by* AIR*. Whence it is clear enough, that the ancient Persians and Chaldeans had no opinion of a *vacuum*; having thus filled all space with *air*, and what they called an *all-nourishing æther*, to which they joined an *intelligent* and *life-giving fire* †.

Some moderns, who have refined upon the theology of the pagans, and interpreted their creed so favourably as to make it differ but little from the *christian* doctrine, have supposed they worshipped *fire* only as an emblem or image of the deity, as the *romanists* make use of pictures to enliven their devotion: but the contrary is strongly to be suspected, from the *attributes* they ascribe to it. For this fire is no dead image of a superior intelligence in the Deity, but is asserted to be endued with an intelligence of its own; it is Πυρ νοερον, πυρ ζωηφορον, πυρ φαινον, ψυχη ουσα πατρος—αθανατος τε μενει, και ζωης δεσποτης εστι—*Intelligent fire, life-giving fire, splendid fire, the soul of the father—remaining*

* Αιθρης μελος, ηελιου τε, σεληνης τε, και οσα ηερι συνεχονται.

† Παντοτροφου αιθρης——Ζωηφορον Πυρ.

ing immortal, and the Lord of life—which expressions are too high to admit of any thing superior. You may indeed render νοερον by the word *intellectual,* which will give a different sense; but from the whole tenor of these oracles such a construction would be unwarrantable.

I hope I shall not stand in need of an apology for wandering thus into the depths of the theology of the heathens, while I professed only to collect their sentiments on *natural philosophy.* For it is conspicuous enough, that philosophy is here so metamorphosed into divinity, that it is scarce possible for me to separate them. With these unenlightened idolaters, wise enough as naturalists, but miserably blind and ignorant of things spiritual, *God* and the *world* were but one and the same thing; and this persuasion gave birth to the whole science of *astrology,* for which the Chaldeans were so much famed; so that if we desire to obtain their judgment on *nature,* we are under a necessity of taking their theological doctrines along with it. I must therefore beg leave to go on a little farther upon the same plan, as there is something in these remains of Zo-

roaster,

roaster, worthy of being brought out to the light.

His philosophy included in it a kind of *physical trinity,* which is evidently made up of the powers of nature, and will serve to teach us, *what* he supposed these powers of nature to be, even the same as we have already found and established from experiments. It was a principle of this philosopher, that—Παντι εν κοσμω λαμπει Τριας, ην Μονας αρχει—*a triad shineth forth throughout the world, over which an unity presides.* This *monad* or *unity* must signify the *sun*; the Assyrians, (that is, the Chaldeans,) according to Macrobius, having worshipped him under the name of Adad, which name, as he tells us, signifies *one* or *unity**. As to the *triad,* I should despair of unravelling so great a mystery, had not another fragment of the same Zoroaster preserved its interpretation—

——— ιερος Πρωτος δρομος, εν δ' αρα μεσσω
Ηεριος, τριτος αλλος ος εν Πυρι την χθονα θαλπει.

As these were undoubtedly designed for *hexameter* verses, a word is plainly wanting at the beginning of the first line, which, according to the sense, the measure of the verse,

* Saturn. lib. 1. c. 23.

verse, and the *poetic dialect* here made use of, must have been Ηελιȣ*: the sense of the whole therefore is this—*The sacred course of the sun, or light, is the first power; in the middle there is an aerial power; and a third is that which cherishes the world with fire.*

Experience will teach us, that natural effects are immediately governed by these instruments of the divine power; and the ancients appear to have been well apprized of it. But what a miserable use did they make of this valuable treasure when they had got it! Here they stopt: this physical triad, by a strange perverseness and abuse of reason, furnished them with a pretence for denying that supreme power which gave birth to all things, and is of a nature independent and distinct from the world of matter.

On the contrary, the fathers of the *christian* church, having shaken off the prejudices of paganism, and being better informed by divine revelation, were always very severe upon the Gentiles for dishonouring God by that vain philosophy which supposed him to be coequal and coeval with matter, a soul of the world, a *tertium quid* made up of matter and

* Δρομος ηλιȣ is the phrase used by Hippocrates, see p. 203.

and intelligence *. Among the rest, Epiphanius, a learned and eloquent writer of the *fourth century*, has some remarks in this way upon the various sects of the Gentile philosophers†; and was so happy as to rescue this *physical trinity* from the ethnic abuses of it, and apply it to its proper use, as an emblem and shadow of the divine personalty. Speaking of the coequality and *co-efficiency* of the *sacred trinity*, against some of the primitive heretics, he says—*Are not these three persons to be understood by every one, as they are appositely revealed to us by light, fire, air; and, I think, by some other similitudes also of visible things, as man, whose understanding is thus ministred unto, is found worthy to receive them*‡?

As I have endeavoured, upon another occasion, to give some proof that my concern for this sacred and fundamental doctrine of our religion is very sincere, I could not help speaking

* Quid enim aliud est *natura*, quam DEUS, & divina ratio toti mundo & partibus ejus inserta? Seneca de Benef. lib. 4.

† Epiphan. Op. vol. I. p. 12. edit. Colon.

‡ Ουκεν τρια ταυτα οντα——εκαστω αξιως νοουμενα, καθως εναντα αποκαλυπτει φως, πυρ, πνευμα· και αλλαις οιμαι ορατεων ομοιωσεσι, καθως αξιος ο διακονουμενος ανθρωπος. Id. vol. I. p. 891.

speaking of this as an hint to ground an argument or rather an *illustration* upon from *nature:* and am persuaded it might be improved, very much at large, to the entertainment and satisfaction of those who can take delight in so sublime and deserving a subject. But as I do not admire digressions, I must content myself at present with only proposing it as an article both ancient and curious; and leave a more particular prosecution of it, either to another hand, or at least to another opportunity.

CHAP. IV.

Some Extracts from two Authors among the Latins, Pliny *and* Seneca: *with some Reflexions on the* Democratic *System.*

AMONG the Latins there are some pieces still extant, which treat professedly of nature; as the *natural history of Pliny,* and the *natural questions of Seneca*; the latter of which is the most complete work of the kind that is come down to us from antiquity.

Pliny

Pliny was certainly no friend to a *vacuum*; he rather chose to follow the judgment of earlier times, and understood the *heaven* and the *air* as two names for one and the same thing*. And lest we should mistake his meaning, he subjoins, that every space which *looks like a vacuum*, is, in fact, a promptuary of this element. The earth and the planets float in it, and are supported by the strength of it: it passes through all things, and makes a part in the composition of all bodies †.

He relates it as the opinion of Posidonius, the mathematical preceptor of Cicero, that the region of the winds, clouds, and vapours, is extended to about 40 stadia above the level of the earth's surface; and that thenceforward, throughout the higher regions, *there is a pure and liquid air, with an undisturbed light* ‡. It is worth remarking, that this ancient geometer hath fixed upon the altitude of 40 stadia (which make nearly 5 *Italian miles*)

* *Cælum* appellavere majores, quod alio nomine *aera*: omne quod inani simile vitalem hunc spiritum fundit. *Plin. Nat. Hist.* lib. 2. c. 38.

† *Ibid.* c. 5. & 6.

‡ *Posidonius* non minus quadraginta stadiorum a terrâ altitudinem esse, in quâ nubila ac venti nubesque proveniant. Inde purum liquidumque & imperturbatæ lucis aerem. *Ibid.* c. 23.

miles) for the extent of the atmosphere; this being the very quantity that comes out, if equal spaces in the atmospherical column should correspond to equal parts in the column of the barometer: whence it seems not improbable, that he was possessed of some experiment for discovering a counterpoise to the pressure of the atmosphere, though his inference from it was not so correct as it ought to have been.

In regard to *fire*, Pliny assures us, it had never been doubted, so far as he was able to find, that the elements are *four* in number, and that fire is one of them *. This fluid is present in the human body, in wood, in stone, and even in water itself. Nature is so replenished with it, from the immense fire of the sun and stars, clouds, burning mountains, and fiery exhalations from the earth, that it ought to be esteemed as the greatest of miracles, that a single day should pass without a general conflagration of the universe †.

Another physical writer among the Romans,

* Plin. Nat. Hist. lib. 2. c. 5.

† *Excedit profecto omnia miracula, ullum diem fuisse, quo non cuncta conflagrarent.* Ibid. c. 107. see the whole chapter.

mans, is Seneca; who asserts positively enough, that there is no such a thing as a vacuum in nature*: that a medium must be concealed within the most *solid* bodies, because *sound* would not otherwise be *transmitted through them*, as it certainly is†. Some philosophers would be objecting, that a bird could not fly through the air, unless there were a *vacuum between its particles*. Seneca affirms, on the other hand, that the several parts in a line of matter cannot possibly affect one another without continuity‡; a position which excludes the whole system of immaterial attractions and repulsions: and that the continuity of water is no hindrance to a free motion of solid bodies in it; because it is the nature of fluids to yield, and *flow backwards with a contrary motion into the space deserted by the moving body.* Upon which

* Nihil enim usquam inane est. Nat. Quæst. l. 3. c. 16.

† Vox autem quâ ratione per parietum munimenta transmittitur, nisi quod solido quoque aer inest. Ibid. l. 2. c. 9. This is one of Du Hamel's arguments for a *subtile æther*, in favour of Descartes; and more, I believe, might be said upon it, than he was aware of.

‡ Nunquam enim contexti, *nisi per unitatem*, corporis nisus est; cum partes *consentire* ad intentionem debent, & *conferre vires*. Lib. 2. c. 6.

which consideration, there is no necessity for an *interspersed vacuum* *.

Of the *air*, and its influence as a physical cause, he speaks nearly in as high a strain as Hippocrates himself. He goes so far as to impute the *cohesion of our bodies* to it, and therefore must undoubtedly have been acquainted with the pressure of the atmosphere, of which the ancients are supposed to have been altogether ignorant †. Where the atmosphere ends, it was his opinion, that a purer *æther* begins, and is extended from thence to the sun and stars ‡. And lastly, he held, that what is called *fire* occupies the whole world §.

We see, then, what hath been the general sense and doctrine of the ancient philosophers, concerning the operations of nature. When I had determined to consult their

 judgment

* Aquarum quoque similis facilitas est: nec de unitate illarum dubium est, quæ sic corpora accipiunt, ut *semper in contrarium acceptis refluant—Nihil autem opus erit inani admisto.* Lib. 2. c. 7.

† Esse autem unitatem in aere, vel ex hoc intelligi potest, *quod corpora nostra inter se cohæreant.* Quid enim aliud est quod tenet ea, quam spiritus? Ibid. c. 6.

‡ Lib. 2. c. 14. Lib. 1. c. 2.

§ Dicimus autem ignem esse, qui occupet mundum. Lib. 3. c. 13.

judgment upon this important subject, I perceived it was necessary to confine myself to these few leading questions—*Whether they had found the world to be* full *or* empty *of matter? What* offices *they assigned to the different* elements, *of which the material world consists?* And, *to what* causes *in special, they thought fit to ascribe the immediate production of* natural effects? Had I not thus prescribed to myself some certain limits, my inquiry had been both endless and unmeaning; and the design of the present work being such as to include only the *causes of motion*, or *first principles* of natural philosophy, it would have been impertinent to have followed the ancients farther than I have done. The main substance of what I have extracted from them, agrees so well with what we had obtained before, by an examination of nature itself, that the *conclusion* at the end of the preceding book will never be suspected of *novelty*, by those who have had patience enough to follow me through the several articles of this collection; and some, perhaps, may be led by this course to entertain a better opinion of its *truth*.

But it now behoves me to confess, that the

the ancients have been applied to for their suffrage, in behalf of some principles widely different from those for which I have here been pleading. Dr. Clarke, in his second reply to Mr. Leibnitz, thought proper to insert the following observation:—"Many "ancient Greeks, who had their philosophy "from the Phœnicians, and whose philo-"sophy was corrupted by Epicurus, held "in general *matter* and *vacuum*; but they "knew not how to apply those principles "by *mathematics* to the explication of the "*phænomena of nature.*" Who could these Greeks be? Neither Pythagoras, nor Plato, nor Ocellus Lucanus, nor Thales, nor Zeno, nor Aristotle, whose names were most ancient and famous in natural philosophy, are found to have acknowledged these principles. But he that is aware of Dr. Clarke's manner of representing things, will not be surprised, when he discovers, that these *many ancient Greeks* were the *Democritic* atheists; who, by the help of an internal power or *gravitating force* in *atoms*, and a *vacuum* wherein these atoms might have room enough to move without being resisted, had dexterously contrived to account, as well for the *formation* as the *preservation* of the world, without

a *Divine Providence.* If the clearest testimonies are of any weight, the brains of Leucippus and Democritus were first delivered of this philosophy. Such as it is, you have a copious account of it in Laertius's life of Epicurus, and in the poem of Lucretius; who, in defence of his *vacuum*, wisely argues against a *fact*, because he could not understand how that *should* be, which really *is* *. This system included some subtile speculations, concerning the sizes and figures of the first principles of bodies, and the appearances that may arise from them, which are not without their use: and hence the followers of it had the denomination of *Atomists*, or *Corpuscularians.* This branch of their scheme was probably very ancient and of good authority, and has, I believe, been cultivated more or less by the philosophers of every age. It was revived in a particular manner in the last century; and Mr. Boyle, to whom we are so greatly indebted, was very fond of solving effects from some certain configurations of the primitive particles of bodies. But how effects can arise, merely from a configuration of the parts of matter, I see not: and it seems as unreasonable to form

* *Lucret.* lib. 1, 371. *Illud in his rebus,* &c.

form a solution wholly and altogether upon such a speculation, as to deduce the demolition of a fort from the *spherical figure* of a cannon-bullet; which indeed is of a form, fitted for its flight through the air, as it comprehends most weight under the least surface; and of a size best adapted to the cylindrical cavity of the gun: but must remain inactive within it, till it receives motion from a proper agent, the consideration of which is infinitely more important than the figure of the bullet, though that also is by no means to be neglected.

Thus far the *Democritic* method of philophizing might be both ancient and innocent; but this, I presume, was not the part upon which Dr. Clarke set a value, as he did not think it worth mentioning; nor could it indeed be of any service to the argument he was upon. It recommended itself to his attention, by its doctrines of a *vacuum*, and an inherent quality of motion in the parts of matter; by which it differed from the best and most universal philosophy of antiquity, and was distinguished as a foundation for atheism.

The derivation of its pedigree from Phœnicia is altogether groundless, and is suf-

ficiently refuted in what we have seen already; as also by what is affirmed of Thales, the *first* among the Greeks who travelled into that country in search of natural philosophy, and maintained, that *there is no such thing as a vacuum in the world. Plutarch*, who informs us of this, adds upon the occasion, that *all philosophers, but the* Atomists, *who denied a Providence, agreed in this doctrine**.

CHAP. V.

The Sentiments of the most eminent of the modern *Writers, subjoined to those of the* Ancients.

SINCE the supposed discovery of a vacuum, some have confidently affirmed, that natural effects are no way to be accounted for, but by the power of the Deity immediately interested; and either the reason of man, or the reason of things, is so altered, that what did serve formerly as a ground-

* *De placit. philos.* 1. 18.

ground-work to atheism, is now recommended as the only sure foundation of natural religion; as if it were impossible for God to act by secondary causes, without tempting us to believe, that such causes were able to contrive and frame a world without his interposition. Those who object to second causes, upon any pretensions to religious motives, must imagine surely, that matter, if there is but enough of it, can move, act, and think, by its own nature. If it cannot, we are in no danger of excluding a divine power, by filling the heavens with a fluid medium: if we suspect that it can, then we make ourselves materialists, that is atheists, in order to confute atheism more effectually. So that this triumph of natural religion over atheism, is either affected, to serve some *hypothesis*, or grounded upon too hasty a judgment of things.

An infallible criterion of simple and absolute atheism, is the exclusion of *final causes.* If you can fix upon two or three of these, which are clear and beyond dispute, as that the *eye* does not see *by accident*, but was *contrived for seeing*, and such like, you answer all the atheists that ever were or ever will be; who are no better than sots and ideots,

ideots, if they can stand out against the testimony of their own senses. For you prove, by a single step of reasoning, that there is a divine mind or wisdom, that hath wrought with a view to certain *ends*, which it hath attained in the most perfect manner. This topic is well pursued by Cicero, in a beautiful and masterly draught of the wisdom and design that appears in the various works of the creation. It makes a considerable part of the second book *de naturâ deorum:* and, in my opinion, this discourse, so far as it is a confutation of *atheism*, is abundantly sufficient for that purpose, and complete enough in its argument, without any farther additions.

But all this, though unexceptionable and unanswerable, is obvious (as it ought to be) to every capacity: it is plain, easy, and old-fashioned; therefore all men are not pleased with it. If you will follow their new prescription, you must bring yourself, in the first place, to believe a *vacuum;* the steps to which are not understood by one in a thousand: then you are to remove the notion of *actio in distans*, which in the last age had some great authorities on its side: then

then you arrive at this conclusion, though not without a considerable stride, that God himself is the sole agent, to whose immediate power, exclusive of all secondary agents, the lowest effects in the world are to be imputed. And if these things are so, then it follows, that there is a God, and you triumph over atheism. But in the mean time, if your foundations should be weak, and experiment should overthrow your arguments for a vacuum, the capital truth of natural religion, as you have contrived to state the matter, will be in a very precarious situation. No good, therefore, can accrue to religion, from *this* method of confuting *atheism;* and some danger is always to be apprehended from new and empirical projects in divinity.

Of this the excellent Lord Bacon was truly sensible; and there is not, in the whole course of his writing, so heavy a censure, as that which he thought proper to pass upon the error now before us. "Certain it is, (says he) "that God worketh nothing in "NATURE but by SECOND CAUSES: "and if they would have it otherwise be- "lieved, it is mere *imposture,* as it were in "favour

"favour towards God; and nothing else "but to offer to the author of truth, the "*unclean sacrifice* of a *lie**."

It is observed by the same author, with that brightness of expression so familiar to him upon all occasions, that "*heat* and *cold* "are nature's two *hands*, whereby she chiefly "*worketh* †." The nature of *cold*, in particular, he proposes as a thing worthy the inquisition "both for use and disclosure of "CAUSES ‡." And he does not seem to have believed that cold is a mere privation of substance, but rather that it is "active "and transitive into bodies adjacent, as well "as heat §." Gilbert, the magnetic philosopher, having possessed himself, as he thought, of an *attractio in distans*, had published the doctrine of an absolute vacuum in the spaces between the celestial orbs. The Lord Bacon, on the other hand, had formed to himself "a theory, according to "which, all space is *filled* either with an "*aerial* or *fiery* nature ‖." He denied also, "that

* *Adv. of Learn.* p. 5.

† *Nat. Hist.* Cent. I. No. 69.

‡ *Ibid.* § *Ibid.*

‖ Theoria nostra negat vacuum illud coacervatum Gilberti inter globos sparsos, sed spatia vel *aëreâ* vel *flammeâ* naturâ *repleri*. Thema Coeli.

"that the pores or cavities of tangible bo-
"dies admit of a vacuum; but that they
"contain either *air*, or a subtile *spirit* pro-
"per to their nature and disposition*." Of this spirit he treats as of a *material* cause, rejecting all those pretended solutions, as unmeaning and unphilosophical, which are deduced from *virtues* or *qualities* in matter, and with which the schools in his time did very much abound. "Whatsoever is invisible (says he) "either in respect of the fineness of the body
"itself, or the smallness of the parts, is but
"little inquired. And yet these be the things
"that GOVERN NATURE principally;
"and without which, you cannot make any
"true *analysis* and indication of the *pro-*
"*ceedings of nature.* The spirits or *pneu-*
"*maticals*, that are *in* all tangible bodies,
"are scarce known. Sometimes they take
"them for vacuum; whereas they are the
"most active of bodies. Sometimes they
"take them for air; from which they differ
"as much as wine from water. Sometimes
"they will have them to be natural heat;
"whereas

* Nullum corpus, nobis notum hic in superiore parte terræ, spiritu vacat.—Neque enim cava rerum tangibilium vacuum recipiunt; sed aut aerem, aut spiritum rei proprium. Hist. Vit. & Mort. Can. 21

"whereas some of them are cold. And sometimes they will have them to be the *virtues* and *qualities* of the tangible parts which they see; whereas they are things by themselves. And when they come to plants and living creatures, they call them souls. And such superficial speculations they have; like prospectives, that shew things inward, when they are but paintings. Neither is this a question of *words*; but *infinitely material in nature*.—As to the motions corporal, within the inclosures of bodies, whereby the *effects* pass between the *spirits* and the *tangible parts*, which are arefaction, colliquation, concoction, maturation, &c. they are not at all handled. But they are put off by the names of virtues, and natures, and actions, and passions, and such other logical words. It is certain, that of all *powers* in nature, *heat* is the chief; both in the *frame of nature*, and *the works of art**."

That Mr. Boyle was nearly of the same opinion with his great predecessor, and always searching for an explanation of effects from *second causes*, must needs be known to those who have looked into his philosophical works,

* *Nat. Hist.* Cent. I. No. 98. 99.

works, and in particular his *History of Firmness*, where he attempts to derive even the cohesion of solids from the pressure of the atmosphere. For, although he was unsuccessful in this, it serves to teach us, what his general persuasion was; and the industry of man, still working upon the same ground of second causes, may in due time be productive of some better fruit.

Dr. Cudworth, author of the *Intellectual System*, is one of those many writers, who have condemned that position, whereby God himself is made to be the sole agent in nature, as improbable in itself, and unworthy of the Deity. As his arguments appear to me to be worthy of consideration, I shall here adopt and support them with some farther observations of my own. First, then, this position *throws down all distinction between God and nature*, and turns every ordinary effect into a miracle. Then again, it is not consistent with *that slow and gradual process in the generation of things, which shews the agent not to be omnipotent*. A plant will advance in its growth, either more or less, as the season happens to favour it: and if the heat and the air be withdrawn from it, it will not grow at all. Is it credible that

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the Divine power should be baffled and overcome by these or any other difficulties? Yet this, impious as it may sound, seems to be the necessary consequence of supposing that power to act in such manner as to supersede the use of all natural instruments.

The falsehood of this position is farther evident, from those *errors* and *accidents*, whereby the formation of things is frequently interrupted. These *argue the agent not to be irresistible; and that* nature *is such a thing as is not altogether incapable of being sometimes frustrated and disappointed by the indisposition of matter**. It is a common observation, that branches of trees, particularly of the ash, will grow out of their legitimate shape, and become flat or fasciated. The ingenious Mr. Hogarth has introduced the figure of a curious specimen of this sort into his *Analysis of Beauty;* where even the aberration of natural causes from their proper scope, appears to be productive of the greatest elegance, but without utility. The like will sometimes happen to a stalk of *asparagus*, if the soil is too stubborn, or a stone lying in the way chances to divert the growth of it. And many other instances must occur to

* *Intellectual System*, Book I. cap. 3. § 4. &c.

to those who employ themselves in inspecting the operations of nature.

It is surprising to see what varieties of figure, structure, and colour, are made to arise in vegetables, merely through some change, either in the efficient causes of vegetation, or the nature and disposition of the materials they have to work upon. Two wild plants of the same species shall be found with leaves of very different figures, only by growing many miles asunder, where there is some difference in the air and in the soil. And there are plants which cannot be kept alive but in their native air, how inclement soever it be; of which we have one example in that large *yellow violet*, so common upon the highest and most westerly mountains of Derbyshire.

Those who follow the method of Linnæus, and distinguish herbs into classes from the various characters in their organs of generation, must have had many opportunities of observing some confusion in the *number* of their *stamina*; so that it is sometimes difficult for those who are novices in the art, to determine to which of his classes a plant ought to be referred.

By the arts of cultivation common among

gardeners, the beauty of a plant may be greatly increased *at the expence of its fructification*: for the doubling of the flower obliterates the rudiments of the seed-vessel, and defeats one end of its being, by rendering the plant incapable of propagating its species by seed. This is sometimes observed to happen, even while plants are left to themselves in their native places. To these we may add all those plants which, being brought into England from countries nearer to the sun, are never *completely formed* in this climate, being always barren and without seed, unless they are assisted with hot-beds and stoves; and many there are which, even with these helps, cannot be brought to any degree of perfection.

The richness of the ground will very frequently occasion some unexpected appearance in plants that are moved into it from a barren soil. The *Herba Paris*, a vegetable of a singular structure, (see plate III. fig. 4.) is always found with *four leaves*, as it grows wild in the woods. And this form is so general to the individuals of the species, that, in its several names, a particular regard is always paid to this quaternity of its leaves: Morison calls it, *solano congener non ramo-*

sum

lum tetraphyllum: C. Bauhine, *solanum bacciferum quadrifolium*: and to those who imposed the name *Paris* upon it, I imagine, its four leaves regularly surrounding the stalk, and the single round berry at the top of it, suggested an idea of *Paris* and the *three goddesses*, with the *apple* of contention in the midst of them. Yet this herb will depart from its natural form, if it is removed into the richer soil of a garden, and bear *six* leaves, instead of *four*. I have tried the experiment, and have such a specimen in my possession.

These things I thought it worth the while to speak of, as so many effects, which cannot with any shew of reason or piety be ascribed to the power of the Deity immediately interested. It is therefore most agreeable to religion, reason, and experience, to conclude with Dr. Cudworth, that there are agents or instruments in the world, whose powers, being only of a subordinate kind, may by certain circumstances be made to vary in their effects, so as to go faster or slower, like a clock with different weights applied to it; and to be even *frustrated and disappointed in their operations by the indisposition of matter*. The *wisdom* of God will also be infinitely magni-

 fied,

fied, if he is found to bring about those things by the mechanism of second causes, to which philosophers have determined the divine power itself to be absolutely necessary. And we may hence derive the only rational encouragement to a cheerful and diligent study of nature. The causes employed are few and simple beyond expression: their effects are infinitely various and wonderful; and to those who begin upon a right foundation, they will unfold themselves every day more and more; nor will the labour of man be lost in the pursuit, till he has acquired as much knowledge of this sort as will do him any good in his present state.

In the judgment of that eminent experimentalist, Dr. Boerhaave, "so great is the "power, so extensive the action, and so "wonderful the manner wherein *fire* acts; "that it was anciently held and adored as "the supreme God, by a nation reputed the "wisest of all others. Thus some of the "chemists, having found its extraordinary "force, took it for an uncreated being; and "many of the most eminent among them, "attributing all the knowledge they had "acquired to this INSTRUMENT, called "themselves *philosophers of fire*; as thinking

"they

"they could not be dignified by an higher "title. There is, however, nothing more "wonderful in the nature of fire, than that "while it is the chief CAUSE and PRIN- "CIPLE of almost all the effects cognizable "by our senses, yet itself is imperceptible "by any sense; being so incomprehensible, "by reason of its extreme minuteness, that "it eludes our nicest research; so that with "many it passes for a spirit rather than a "body*." That the world should be so full of this fluid, and we should be so little sensible of it, is indeed very astonishing. But the wonder wholly ceases with those who argue, upon this account, that there is no such thing: that if there were a plenum of subtile æther round about us, we ought to move with as much trouble, as if we were wading through an ocean of mercury. Now, if you were to tell an ignorant man, that if the greatest diameter of the trunk of his body is equal to 15 inches, he is pressed downwards to the earth by a weight of more than three thousand pounds, he would hardly believe you; but would argue, that, in such a case, he ought to be crushed to death; whereas he moves easily, and feels no impediment.

* Boerhaave's Chemistry, by Shaw; vol. i. p. 206.

diment. Yet this is known to be unquestionably true by those who understand the *barometer*, or have seen any experiments with an *air-pump*. And what is still more surprising, there is another agent every-where present, a column of which, equal only to an ordinary needle in diameter, when in motion through the body, shall make you sensible of as great a force as if you had received a blow upon the arms with a sledge hammer; and the muscles of the strongest man in the world can do nothing against it. How does it happen that we can pass a single day without being shattered to pieces? For if so minute a column can exert so terrible a force, what are we to expect from a column that has the whole body for its base? The reason that we feel no harm is this; that force is every way opposed to force, and none of it is perceived while the *equilibrium* is preserved. When that is by any means interrupted, an unexpected force immediately discovers itself. We shew but little experience of nature, and as little gratitude to the author of it, if we dispute against the reality of a subtile medium, because our lives are not rendered miserable by the force of it. For God, with equal wisdom and goodness, hath

put

put both our bodies and this matter into a mechanised state, so that it shall do us all the good that is required, without standing in the way to do us mischief. And this matter is what Dr. Boerhaave meant to speak of under the name of *fire*.

The element of *air* is described by the same author as "an universal, necessary, "and most efficacious *instrument*, which "nature is perpetually applying in almost "all her works *." Experiments, as he ingenuously confesses, often led him to consider, "whether God did not originally create "fire and pure elastic air, *and distribute* "*them through the whole universe* †."

To these authorities let me add that of Dr. Berkeley, the late excellent and universally learned bishop of Cloyne, whose opinion may be learnt from the following extract— "Without instrumental and second causes, "there could be no regular course of na- "ture; and without a regular course, nature "could never be understood. The order "and course of things, and the experiments "we daily make, shew there is a mind that "governs and actuates this mundane sys-

* Boerhaave's Chemistry, vol. i. p. 381.

† *Ibid*. p. 420.

"tem, as the proper real agent and cause; "and that the *instrumental cause* is pure "æther, fire, or the substance of light; than "which it doth not seem necessary from "phænomena to suppose any medium more "active and subtile. As for *attraction*, it "cannot produce, and in that sense account "for the phænomena; being itself one of the "phænomena produced, and to be account- "ed for. What is said of forces residing in "bodies, whether attracting or repelling, is "to be regarded only as a mathematical hy- "pothesis, and not as any thing really ex- "isting in nature*."

The Abbè le Pluche, whose ingenious and spirited writings will give both pleasure and improvement to every reader, appears, by his productions, to have laid in a large stock of experimental knowledge, with a competent degree of skill in mathematical learning. He has taken a liberty of following nature and observation, as a philosopher at large, not devoted to any sect or system: and his inquiries, it seems, have led him to this conclusion; that "there are but three known "fluids in nature, which, by their continual "activity, are the *principles of all motion*;

"and

* Siris, Art. 160, 154, 243, 234.

"and these are, *light*, *fire*, and *air* *." How precisely does this passage coincide with the judgment of antiquity! The principle that was maintained as the fundamental truth in physics, above two thousand years ago, by Zoroaster and Plato, discovers itself again, at this distance of time, to a naturalist who inquires in a proper manner. This coincidence would have happened oftener than it has, if philosophers had conducted themselves as the scholars of nature, and not as its masters. For nature is the same now as it was then; and experiment, duly consulted, would speak the same language in all ages. The fault is in men; who, by affecting to surprise the world with building things high and marvellous after a model of their own framing, fall into confusion and self-contradiction; while they overlook what is truly valuable, because it is cheap and common, and hath not an air of mystery and darkness scientific.

The conclusion of this celebrated author might, I think, be deduced from premises very plain and obvious without any assistance from *Algebra*, *Geometry*, *Greek*, *Latin*, or

* *Spectacle de la Nat.* Vol. 4. Disc. 12. p. 119. of the English translation.

or *Hebrew*. For what scholarship doth it require to be able to distinguish that *light* gives sight to the eyes? that *air* is the breath of life? and that, without *fire* or heat applied in its proper degree, the blood is congealed, and the limbs are inflexible? All this is evident to the most undisciplined apprehension; for a man is no sooner born into the world, than he makes most of the experiments requisite for the obtaining of this knowledge; and he may challenge the most subtle philosopher to name that substance or fluid in the whole universe, which can supply the place of any one of these. What then can be plainer, than that these, as the Abbé le Pluche hath rightly affirmed, are the physical *principles of all motion?* And where can the naturalist employ his labour to so much advantage, as in deriving effects from these causes? For although they are obvious to the vulgar in many of their operations, the most able disquisitor might pursue them for a thousand years, and find, after all, that he had left a great deal of matter untouched.

The phænomena of *light* were cultivated with equal industry and sagacity by Sir Isaac Newton: and what a scene does this fluid furnish out to a contemplative mind, by the

glorious variety of its colours, the amazing velocity of its motion, its reflexions, refractions, and the inconceivable subtilty of its substance! After it had been examined and re-examined by this great geometrician for many years; and after the speculum of Villette had surprised the world with the effects of the solar rays upon bodies exposed to the focal heat of it; *electricity* broke in upon us, as it were by accident, began a new epocha of philosophy, and discovered light to be a most powerful and universal cause of motion, with which the whole world is filled; opening to us a fresh storehouse of effects as inexhaustible as the science of optics.

Many effects of the *air* are so common, and withal so very important as to be taken notice of by every writer on natural philosophy. It is plainly acknowledged as a material cause of motion, by those who imagine they get rid of such things, if they can but exclude *the air* from a glass receiver. Many things curious and surprising occurred to Dr. Hales, when he undertook to analyze this element; and he discovered, what others appear to have known many ages before, that it makes a part in the composition of all bodies which derive their activity from this

this substance, so artificially combined with them for that purpose.

With the wonders that present themselves to us in a natural history of *fire*, any reader may become acquainted, by perusing Dr. Boerhaave's incomparable discourse upon that subject. The series of well chosen experiments there laid down, will open to him many of the powers and uses of that element, both in nature and art, and justify the highest expressions used by that learned chemist in the praise of it.

Of these *principles* much is already known; more than enough to reward the labour that is spent in searching after it. That much more yet remains to be known, I am induced to believe upon many considerations; and upon this amongst the rest: that some eminent men, of late years, who have been best qualified to make discoveries and improvements, have been unhappily pre-engaged to schemes of another kind; and, instead of cultivating the knowledge of these fluids, as the natural principles of motion, which is the light wherein they ought to be understood, have regarded all material instruments as the common enemy, because hurtful and destructive to their systematical *vacuum*: and if

if any such thing has discovered itself to them in their researches, it has either been strangled in the birth, or represented as an underling to the old ghostly principles of *attraction* and *repulse*; which have no meaning in themselves, and do effectually shut the door against all farther advancement. If I wish that those who are fond of natural philosophy may shake off these prejudices, it is only with this view, that their labours in that delightful study may be attended with more pleasure to themselves, and profit to the public.

CHAP. VI.

The Judgment of the Holy Scripture *concerning the System of Nature.*

THE mind of that man, who conceives so falsely of the divine oracles, as to believe that they maintain any opposition to true and useful learning, hath been debauched by some sophistical reasonings, or debased by

by grovelling and unworthy pursuits. They arm us indeed against *vain* philosophy, and all the empty fictions of the human imagination, which bring forth neither pleasure nor profit to those who are occupied therein. But then they invite us, in the sublimest strains, to consider the *works of God*; whose counsels and perfections, as they are displayed in the creatures, will ever be best understood by those who study *them* with humility and attention. Learning and philosophy did never shine more bright, than when they met together with faith and religion in the mind of the excellent Lord Bacon *; whose opinion it was that the wonderful works of God do *minister a singular help and preservative against unbelief and error*. If there are any philosophers so void of understanding as to regard the science of nature only as a tower of state for a proud mind to raise itself upon; and to esteem themselves as licentiates in incredulity, because

* If the reader desires to have a taste of the Lord Bacon's character, from some piece wherein the *christian* and the *philosopher* are united, I would recommend his *New Atlantis*; a discourse which seems to have given the first hint for the establishing of philosophical academies in Europe, such as is the *Royal Society of London*, &c.

cause they make some figure in philosophy; it may possibly do them good to look back upon the example of this great man, who preserved a mind untainted with the pride of heresy or infidelity; and was not more to be admired for his extensive learning and experience of nature, than for his theological skill and penetration into the wisdom of the sacred writings. "Two books or volumes of study (saith he) are laid before "us, if we will be secured from error: first, "the scriptures, revealing the will of God; "and then the creatures expressing his "power, whereof the latter is a key unto the "former *." These two volumes being so nearly related, I shall conclude this treatise with a short and humble inquiry into the judgment of the holy scripture; which the all-wise author of it hath so adapted to the exigencies of man in his present state, that the information it occasionally gives us, concerning the visible works of God, will warm and improve the hearts of the most simple, while it conveys light also to the understandings of the most learned.

1. In the first place, then, we are taught, that the same God, who created the world in wisdom,

* *Adv. of Learn.* B. 1.

wisdom, *upholds** it in mercy; that in him we live, and move, and have our being. If the sun gives us light and warmth, it is *his sun*, which he *maketh to rise* on the evil and on the good. If the clouds pour down their water upon our fields to nourish and bring forward the fruits of the earth; it is he that *sendeth rain* on the just and on the unjust†. To him, therefore, the blessings that are dispensed to us in the ordinary course of nature, are to be devoutly ascribed, as to the primary source of all life and motion. And this conclusion will be equally true, whether God is supposed to distribute the benefits of nature from his own hand immediately, or by the mediation of some secondary causes of his own appointing; for, either way, the real government of the whole can terminate only in himself.

2. Some will dispute against the operation of second causes, as thinking it to derogate from the *power* of God, that he should *stand in need* of their *assistance*. But they should remember, that God did not make the world because he himself stood in need of any thing; it was for his own good pleasure, and the benefit of his creatures; and with

* *Hebr.* 1. 3.

† *Mat.* 5. 45.

with the same views he established the operations of second causes; he consulted *our* wants in this matter, and not his own. For man is a compounded being, made up of different parts, that claim a kindred with two different worlds, the visible and the invisible. The part, in him, which is natural or bodily, must be supported by natural powers: the superior or spiritual part, by God, *who is a spirit,* and whose powers alone can possibly extend to the wants of it. When nature shall sink, and the spiritual world open upon us, God himself will then take the place of all inferior causes *; and even under the present state of things, a spiritual interposition is not wanting in the *Christian* dispensation: but then it is calculated for the benefit of man's *spirit;* while his body is still left to the ways of nature. To misrepresent the divine power and essence as a *physical* agent, is to confound the two kingdoms of nature and grace; which, as two parallel lines, follow a like course, but can never be made to touch; and to lose sight of that great and beautiful distinction, an adequate understanding of which, in all its

 branches,

* See *Rev.* 21. 23.

branches, would be the consummation of human knowledge.

3. The government of nature, then, by *second causes,* is most suitable to the real *fitness of things.* It is the course God hath thought proper to fix upon, as serving best to his own glory and our good. Experience shews it; antiquity confirms it; and the scripture also, without condescending to treat of it minutely as of a science, hath declared it in such language as cannot be made to speak any other sense without art or violence. That this matter may be brought to a short issue, it will be proper to have in view those *questions* above-mentioned *, by means of which I kept myself within a tolerable compass, when I collected the doctrine of profane antiquity. And first, let us ask, with all submission, whether the world, according to the sacred account, *is full or empty of matter?*

4. We have learnt from Pliny, that it was a custom with the ancients to give the name of *heaven* to the elements that fill the heaven—*Cœlum appellavere majores, quod alio nomine, aera:* and again, *quid esse mirabilius*

* See page 324.

lius potest aquis in cœlo *stantibus?* meaning the *clouds* supported by the *air**. Cicero has a like observation concerning the element of fire—*Ardor cælestis, qui* æther, *vel* cœlum, *nominatur* †. Who then will be surprised, if the scripture, the undoubted source and original of the heathen cosmogonies, and the most ancient book in the world, should be found to speak in the style of antiquity? And certain it is, that, by the word *firmament*, which occurs so frequently, and by the *heavens* when that word is spoken in a physical sense, those *elements* are to be understood which are distributed throughout the heavens. For the heavens are historically treated of as a part of the works of God; and it would be repugnant to truth, that what is nothing in itself but empty space, should be declared to have been *made* and *finished* ‡. It may indeed be objected, that by heaven is meant the visible furniture of the heaven, the orbs of the sun, moon, and stars: but this could never be the design of the history, because the *host*

* Pliny, lib. 31, c. 1.

† Cic. de Nat. Deor. lib, 2, c. 15,

‡ Gen, 2. 1, 4,

of heaven is mentioned apart, and distinguished from the heaven itself.

5. From the New Testament we learn—*that the heavens being on fire shall be dissolved, and the elements shall melt with fervent heat**. Whence it follows, first, that the *heavens* are *material;* they could not otherwise be set *on fire.* Secondly, that they consist of *elements* capable of a *dissolution;* for the terrestrial elements are not here to be understood—the *earth also, and the works that are therein,* being mentioned immediately after. And thirdly, that the conflagration of the great day shall be brought on by a total conversion of the ætherial matter into a devouring *fire:* a tradition of which went abroad into the world very early. It was taken up as a main article of philosophy by the *Stoics;* and seems not to be improbable in the eye of reason, as it passed for the *greatest of miracles* with an *heathen*†, that this universal conflagration had not happened already; considering how abundantly nature is furnished with the materials for such a catastrophe.

6. This *substantiality* of the heavens is farther

* 2 Peter, 3. 12. † See page 321.

farther confirmed from the use and meaning of the word *firmament*, which is synonymous with that of *heaven*. There is indeed a vulgar doctrine, such as might accord well with the genius of monkish expositors in the dark ages, when the solid orbs of Aristotle were in fashion, that the *firmament*, spoken of in the scripture, signifies a kind of solid arch, or inclosure of the world, like a cieling; in which the stars are placed, as so many brass nails, stuck upon the inner surface of an hollow sphere. The futility and falsehood of which will appear from the application of this term: for the sun, moon, and stars, are said to have been set *in the firmament;* and no system did ever yet assign the same sphere to all these bodies, because our senses must assure us of the contrary. What can follow, then, but that the firmament is a medium, extended from the region of the fixt stars, to the places of the sun and moon? It is farther said, that *fowls*, called in other places of the scripture, the *fowls of the air*, and the *fowls of heaven*, (which expressions being compared, will shew us, by the way, that the *heaven* and the *air* are one thing in the language of the scripture,)

scripture,) fly *in* or *upon* this firmament *. Therefore, it is extended all the way from the earth, through the regions of the atmosphere, in which the fowls fly, to the sun and moon, and from thence to the fixt stars and beyond. The margin of our English version has the word *expansion* instead of *firmament;* by which, as the most rational expositors agree, the *expanded æther,* or *diffused body of the air,* is to be understood. And it was well observed by Grotius, that the Chaldee paraphrast upon those words of the 19th Psalm—*the firmament sheweth his handy work*—gives this interpretation—*they who consider the* air, *will tell of the handy work of God.* It is farther remarkable, that Plato used the Greek word Ταπις in the same sense; of which Serranus observes—*quod quidem vocabulum* aeris *naturæ significandæ accommodatum est* †. These short hints are sufficient to prove, that a *vacuum* in the *heavens* is not more opposite to nature and experiment, than to the most simple declarations of the Old and New Testaments. It may occur, as a collateral argument, to those who study

* Gen. 1. 20.

† See his Preface to the Timæus, vol. 3. page 11.

study the oriental languages, that the Bible has no word in the original to denote *space*, as distinct from body; having expressed it by the word that signifies *air* *.

7. But we are now to ask another question; whether God, in his government of the natural world, acts by his *immediate power*, or makes use of *matter* as his *instrument?* The answer, I should think, might follow naturally as an inference from what we have heard already. For if the *heavens* consist of *expanded æther*, this substance must either stop the motion of the heavenly bodies, as the mathematicians, if we will understand the thing in their way, have very well demonstrated; or be instrumental to the conservation of it. And as the former part of this alternative is false by observation, the latter part of it must be true; whether we are able or not to investigate and assign such a mode of operation to the matter of the heavens, as shall stand the test of a severe examination.

8. That matter is *instrumental* in the hands of God for the bringing to pass his purposes in nature, is at least to be suspected, from what happened in the beginning of the

* Gen. 32. 16.

the creation. It could not be without some good and sufficient reason, that motion was *first* impressed upon the celestial elements of light and air. If these were to be instrumental in the formation of other things, as experiment shews thĕm to be now, the reason is plain in itself, and worthy of an inspired historian. And then, even the order and process that is observed in the sacred history of the creation, will suggest to us what may be gathered in a more direct manner from some other places of the scripture. For there are expressions, which allude to, and acknowledge an efficacy of the heavens upon inferior things. The *powers* of the heaven, which are to be *shaken* * in the last day, must signify those natural powers, or material forces of the heavens, by which the visible world is now supported and moved in a regular manner, according to the laws of nature; and not any invisible *powers of the world to come;* because they are mentioned with the sun, moon, and stars, the other members of created nature. There was, it seems, a fit occasion to make an exhibition of these natural powers, when the apostles were to be endued with invisible *power from on high* upon

* Matt. 24. 29.

upon the day of Pentecost; that power having been communicated under the external signs of a *mighty wind* and *flames of fire;* to which two elements, men of all ages and nations, as it were with one voice, have ascribed the powers of moving and governing the natural world. And if they were right in this, it is not strange that these should have been fixed upon as the fittest and most instructive emblems of invisible power. In the Book of Job, which, to such a reader as the Lord Bacon, appeared *pregnant and swelling with natural philosophy* *, the *heavens* are affirmed, by plain inference, to have a *dominion in the earth* †. A question is put to Job by the Maker of the world, whether he was able to fix this dominion by any power or wisdom of his own? which does necessarily imply, that such a dominion is really fixed by the power and wisdom of God. Loose-thinking and ignorant readers of scripture may despise the philosophy of the passages I have hitherto mentioned: but those who examine the works of God without prepossession, will soon discover by experience, that although they are very short, they

* Adv. of Learn. B. 1.

† Job, 38. 33.

they contain the seeds of much knowledge; the most obvious sense that can be gathered from them, being such as agrees best with all the experiments we are able to make.

9. That matter is employed as an instrument in the hands of God, is farther evident, in that he made a mist or exhalation to arise from the earth, for the growth of vegetables, even at their first formation *. When the waters of the flood were to be carried off, he made *a wind to pass over the earth* †. When the plagues of Egypt were inflicted, a *wind* brought the locusts; and another wind drove them away ‡. When the Red Sea was divided, the waters were made to go back by *a strong east wind,* which parted the waves, and laid the bottom dry, for the passage of the Israelites §. But these, it may be said, were *extraordinary* occasions: and I am not unmindful of it; as they are so much the more to my purpose on that very account: for thence it appears, that even upon such occasions, where the case will admit of it, God prefers the method of bringing his purposes to pass by *natural means;* after which, it would surely be unreasonable

* Gen. 2. 6.
† Ibid. ch. 8. 1.
‡ Exod. 10. v. 13. 19.
§ Ibid. 14. 21.

reasonable and absurd to deny the use of such means in the *ordinary* course of nature. And the scripture itself will agree with us in this conclusion. For when the *sun* is said to RULE over the day, and to have been made for this end, what can we understand by it, but that he acts as a vicegerent, and is invested with a mechanical power of giving light, life, and motion, to such objects as are ordained to receive his impressions? All nature revives, and puts on a new face, when he approaches nearer to us in the spring; and sinks into a temporary death, at his departure from us in the winter. That he acts, in a mechanical manner, is also certain; because a chain of matter is continued all the way from the agent to the object. His power consists not in any immaterial quality, because it observes the same geometrical law with the diffusion of his light; and his efficacy upon the productions of the earth is greatest, when the greatest angle is formed between the horizon and his *rays;* though the solid substance of his body is then most remote from us, as the astronomers very well know. A good telescope will shew us what changes are produced in the refraction of the atmosphere, and what a tumult arises in

the air from the agitation of the sun-beams in the heat of the noon-day. The heaven seems transparent and undisturbed to the naked eye; while a storm is raised in the air by the impulses of the light, not unlike what is raised in the waters of the sea by the impetuosity of the wind. It increases with the altitude of the sun; and when the evening comes on, it subsides almost into a calm. A sight this both edifying and instructive, and such as we ought not to behold without calling to mind those words of the devout Son of *Sirach—The sun, when it appeareth, declareth at his rising a marvellous INSTRUMENT, the work of the Most High* *!

10. Can it be thought now, that God performs those things by *immediate* power, which, as we can see and feel, do follow the course of the sun, and are performed by *his* mediation? Philosophers, who contend so eagerly for the immediate influence of a Divine power *in nature*, should blot this luminary out of the heavens; and their arguments would have a little more weight. God hath reserved to *himself* an office more suitable to his nature, than the office they have thought proper to assign him; even that

* Ecclus. 43. 2.

that of giving life, light, and knowledge to the mind or spirit of man. As to the light of the body, that and all the wonderful effects of it are plainly administered to us by the sun, as by an engine or minister subservient to the purposes of its Creator. But some there are so unhappy as to mistake the œconomy of God, both in the *natural* and *moral* world. If you will take their judgment, God, as a natural ruler, is to have the task of moving those portions of matter, which are moved and ruled by the the sun, the work of his hands: while man is to assume the office of the *Father of spirits*, and administer light to his own understanding. In *religion*, which is the province of the Deity, and where there is a *dignus vindice nodus*, all is to be *natural;* but in nature, all effects are to be miraculous! Thus wretchedly will mèn reason, when they think philosophy hath advanced them into a sphere superior to the un-philosophizing simplicity and truth of divine revelation.

11. That we may learn, once for all, what *species* of solution is authorised by the scripture, it will be best to fix upon some particular instance; and there is none more proper than that of *vegetation*. The *earth* is said

said to *bring forth grass:* this is the *effect.* The first cause of it is the power of God, to whom all things owe their being, and by whom all things consist: for *he causeth the grass to grow for the cattle, and herb for the service of man**. But then it is also said, that *the tender grass springeth out of the earth by clear shining after rain†*. Therefore God is the primary cause; the sun is the instrumental cause; while the earth, softened and dissolved by the drops of rain, supplies the materials. This account, plain and simple as it is, gives us the out-lines of all that can be said upon the subject, and guards us against every fundamental error. It condemns the impiety of the heathen idolater, by referring the whole glory of the work to a power superior to matter: corrects the well-meaning ignorance of the philosopher, who would confute atheists, by evacuating the world of second causes: and leaves us in possession of that ancient and valuable doctrine, that some of the elements are appointed to rule over, and give motion to the rest.

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* Psal. 104. 14. † 2 Sam. 23. 24.

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POSTSCRIPT:

CONTAINING

THE AUTHOR'S REMARKS ON SOME PASSAGES OF THE FOREGOING WORK.

On Book I. Chap. III.

PAGE 35, line 14, &c. To understand the objection which the author endeavours to obviate in this place, it is necessary to have some little knowledge of the *theory of falling bodies.* For the sake, therefore, of such readers as have not considered this subject, and to save them the trouble of having recourse to other books, I shall here subjoin an account of it, and try to make it easy to those who have never accustomed themselves to mathematical reasonings.

In

In the right-angled triangle ABC, (plate II. fig. V. p. 111.) the angle CAB, which opens wider, by equal degrees, from the point A towards BC the base of the triangle, expresses *a motion uniformly accelerated.* The leg AB expresses the *time* in which this acceleration happens; and this time is divided into three equal parts or moments, as A 1, 1 2, 2 B. The small lines in the triangle A 1 *k*, repeated at equal intervals, and increasing in length by equal degrees, denote equal accelerations of the velocity from the instant in which a body begins to fall: and the small equal lines in the square 1 *m*, denote an equal velocity during the time expressed by the side 1 2.

These things being first considered, if we now attend to the *figure*, it will open to us all the consequences of these positions.

I.

The line 1 *k* will express the velocity acquired by a falling body *at the end of the first moment of time.* The line 2 *l* will express the velocity acquired at the end of the second moment; and BC the velocity at the end of the third.

II.

II.

If the body, during the second moment of time, should retain the velocity I *k* which it had acquired at the end of the first, the square surface 1 2 *m k* will be described; for this surface is generated by a continual repetition or motion of the line I *k*, during the time 1 2; as the area of the triangle A I *k* is also described by an uniformly increasing velocity during the time A I. But the area of the square is manifestly *double* to the area of the triangle. Whence it appears, that a body moving on, during a second moment, with the velocity acquired at the end of the first, will fall *twice as far* in the second moment as in the first. And the same will be true universally, that the velocity acquired at the end of any given time, will carry the body twice as far in the same time.

III.

But if the velocity continues to increase uniformly during the second moment, then the space described will be as 1 2 *l k*, which is *thrice* as great as the triangle A 1 *k*.

IV.

The *whole space* described by the body in the two first moments, will be as the area A 2 *l*, which is equal to four times the area A 1 *k*: whence it follows, that the space described by the body in its fall, is as the *square of the time* in which it falls; for here the time is 2, and the square of it is 4.

V.

In the *third moment*, were the body to fall with the velocity 2 *l*, during the time 2 B, the space described will be as the rectangle under the time and the velocity, that is, as the rectangular space 2 B *n l*, equal to four times A 1 *k*. But as the velocity is still uniformly increasing, the space will be as the area 2 B C *l*, five times as great as A 1 *k*. And thus will the rectangle under the time and the velocity be always *increased by unity*.

VI.

As the triangles A 1 *k*, A 2 *l*, A B C, are all *similar*, or such as have all their three angles *respectively equal* to one another; then, as A 2 is the double of A 1, 2 *l* will be the double of 1 *k*; and as A 2 expresses the *time*, and 2 *l* the

the *velocity,* where the time is double, the velocity is double, &c. Therefore the *velocity is as the time.*

VII.

If the spaces described in each moment be considered *separately,* then the space in the first moment will be as 1, in the second as 3, in the third as 5, in the fourth as 7, and so on in an arithmetical progression; the common difference being 2.

If we would apply this *theory* to *practice,* it is first to be learnt, that in one second of time bodies are found to fall 15 *Paris* feet and 1 inch, that is 16 feet and something more of *English* measure; but we shall neglect this small quantity, and suppose the whole space to be 16 feet in a round number. This hath been discovered with sufficient exactness from the *motion of pendulums,* between which, and the rectilinear descent of heavy bodies, there is so close a connection, that neither of these can be understood independent of the other. It being allowed, then, that the space fallen through by a body in the first moment of time is 16 feet; it follows, from N° IV. of the theory, that at the end of the second moment it will have fallen $16 \times 4 = 64$: at the end

end of the third moment $16 \times 9 = 144$: at the end of the fourth $16 \times 16 = 256$, &c. All these spaces being as the *squares of the times.*

Hence, if the space be given, through which a body is to fall, we may collect the time wherein it will finish its descent. For let the number of feet in such a space be divided by 16; then will the square root of the quotient express the time sought, in *seconds* and parts of a second. Thus if the space be 144 feet, $144 \div 16 = 9$, of which the root is 3. And the converse of this will be equally true; for if the *time* be given, the space through which the body hath descended may be found from it. If we should desire to learn the depth of a well from the surface of the earth to the surface of the water, let a bullet of lead be dropt into it, and let us suppose this bullet to strike the water in 5 seconds. The square of 5 is 25, which being multiplied into 16 feet, the product will be 400 feet, equal to the depth of the well.

Thus again, were we to see a mass of burning matter, or a large red-hot stone, shot upwards from the mouth of a volcano, and could observe accurately that the whole time of its flight in the air amounted to (as we

will

will suppose) 30 *seconds*; we may thence collect the height to which it arose. For a projected body will both rise and fall in the same time; therefore we are to take half the time above-mentioned, or 15 seconds: then it will be $15 \times 15 \times 16 = 3600$ feet, or 1200 yards, which is not far short of $\frac{3}{4}$ of a mile.

But we are to observe, that, in the application of this theory, two things are taken for granted, before we arrive at any one of these conclusions. First, that the theory itself is true in practice to a mathematical exactness. That it is very nearly so, may be fairly concluded from the experiments which have been made; but nothing more can be concluded with absolute certainty. Secondly, that the motion is performed without any impediment; in other words, that it is performed in vacuo, or in a medium that gives no resistance; which is false in fact: no experiments of any considerable compass having been made, or being possible to be made, without a great degree of interruption from the resistance of air. Upon this account, the well, whereof you are finding the depth, will not be so deep as may be imagined by several feet; nor will the stone, projected from the volcano, rise near so high as we have already con-

concluded. This resistance of the air will be different at different seasons: and to find the absolute quantity of it at any time, and in any particular experiment, is a problem so difficult and complicated, as hardly to admit of an adequate solution.

In the experiments made by Mr. Hawksbee, of which we have an account in his Physico-Mechanical Experiments, p. 278, and in Sir Isaac Newton's Principia, lib. 2. prop. 40, some glass balls, filled with quicksilver, were observed to fall 220 feet in 4 seconds of time. By the theory they should have fallen 256 feet: therefore, the resistance of the air, added to some error in the performance, diminished the space by about one-seventh of the whole. Some other experiments made by Dr. Desaguliers with balls of lead (see Philos. Transact. N° 362. p. 1071), and executed with a better address than these of Mr. Hawksbee, came nearer to the theory. But let us consider that when these balls touched the ground, supposing them to have descended through a space of 256 feet, they moved only at the rate of 128 feet in a second: and what is this to the velocity of light? which, according to the usual computation, moves above a million of times swifter

swifter than a cannon-bullet. Should this fluid be the natural cause of gravity, and should the spaces described be less than the theory requires, on account of a nearer approach in the velocity of the body to the velocity of the fluid that moves the body, such a discovery is far beyond the reach of all human experiments.

If what hath been here said, should tempt an inquisitive reader to search farther and deeper into the application of this theory of falling bodies to the motion of pendulums, the flight of bombs and other projectiles; he may find satisfaction by perusing part i. c. 6, &c. of Mr. Rowning's System of Natural Philosophy—S' Gravesande's Elements of Nat. Phil. by Desaguliers, b. i. c. 19 & 24—Mr. Maclaurin's Account of Sir Isaac Newton's Discoveries, b. ii. c. 5. Or see Dr. Keil's Introd. to Nat. Philos. lect. 15 and 16; than which there is nothing more exact and complete upon the subject.

On Chapter IV.

Page 52, l. 27, &c. In order to prove by some easy experiment, that the resistance which a body gives to any force that is ap-

plied to put it in motion, is *just so much as ought to proceed from the action of gravity upon it, and no more*; I considered, that if the resistance in the ball of a simple pendulum should proceed wholly from its gravity; then the same force ought to move it more easily through a segment of a greater circle, than through a segment of a lesser.

Having put together an *extempore apparatus*, I took two balls of lead, the greater of which weighed one pound and an half, the lesser one quarter of a pound. These were suspended by lines, so that the centre of each ball, being at equal heights, was 28 inches below the points of suspension. A graduated scale being fixed parallel to the plane of their intended motion, I drew the lesser ball aside to 24 divisions from the perpendicular, and having let it fall against the greater, perceived that the stroke of it occasioned the greater ball to move over 4 divisions and $\frac{1}{2}$ from the perpendicular. Then I suspended the greater ball from a point 7 feet and 8 inches above its centre; and letting go the lesser ball from the same distance as before, found that the application of the same force did now occasion the greater ball to move over 9 divisions and $\frac{1}{2}$ very nearly.

There-

Therefore, in this latter trial, where the distance of the heavier ball from the point of suspension is almost *quadruple* of what it was before, the resistance becomes lesser than before by about *one half.*

The *times* of the vibrations of different pendulums being in the subduplicate ratio of their lengths, their *velocities* compared with each other will be inversely as the square roots of their lengths; that is, if the length of the greater pendulum be quadruple, and its time of vibration double, its velocity in a similar arch will be ½ the velocity of the lesser pendulum. In this experiment, then, the resistance is lessened in the same proportion with the velocity: but the velocity is deducible only from the active force of gravity; therefore, the resistance must be owing to the same force. For if the resistance here found be such as ought to flow naturally from the gravity of the body, and no other resistance is to be discovered; must it not follow, that what has been called a *vis inertiæ* is but the same thing with the force of gravity? if not, how are they to be distinguished in this experiment?

That the resistances above-mentioned do not exactly coincide with the inverse ratio of

of the square roots of the lengths, which are 5,29 and 10,20, but deviate from it a little, may be imputed to some small degree of elasticity in the leaden balls. However, this error, so far as it may concern my argument, is on the right side.

From what hath been said there arises this corollary—that *the resistance of any solid pendulous body may be so diminished as to be less than any assignable quantity: or, that a body, how large soever, may be moved out of its place by a force how small soever.* I mention this as a matter of curiosity, though I cannot but regard as trifling all mathematical conclusions which are remote from fact and the common course of things.

In defining the *vis inertiæ*, Sir Isaac hath observed, that *a body exerts this force, only when it is made to change its state by some force impressed upon it.* But certainly the force that keeps a body in its state, and the force that resists a change of that state, must be the same thing: so that, in our experiment, the ball is either brought down to the lowest point of the circle, and kept at rest there, by the *vis inertiæ*, which is false; or the force of gravity which brings it to the lowest point, and would keep it there at rest,

ing them, gives a retrograde motion to the points of the wire; just as a chair, if placed upon casters, will run backwards, when the person sitting in it pushes against the wall with a stick. If the wall were out of his reach, his stretching out the stick would make no impression upon the chair: and the streams of fire will be equally insufficient to produce a motion in this machine, if there be no *air* within the sphere of their activity. To prove this, I made the three following experiments.

Experiment I.

I set the machine upon the plate of my air-pump; and having covered it with a large receiver, electrified it by means of a wire passing down to it through a collar of leathers. While the receiver remained full of air, the machine made its revolutions as well within the glass as it had done before in the open air.

Exp. II.

The same trial being made when the receiver was exhausted, no motion ensued. The room being made dark, the operation of the electrical machine was continued: and it

On Chapter V.

Page 68, l. 4. Some other motions like to that of the two lamps may be contrived in a different manner. Fix a needle upon a pillar of glass or sealing wax four or five inches in length, and place a small wire upon it, pointed at each end, and bent into the shape expressed by *fig.* 2. of *plate* I. Let this little machine be so placed, that you can electrify the brass cap in its centre by sparks from a wire hanging perpendicularly over it, but not touching it. If the instrument is well made, and the fire strongly communicated, the wire will turn upon its centre as fast as the flyers of a common jack: and if the room be darkened, you will see a ring of light formed by the electric æther as it streams from the points of the wire.

This motion is so far from being stopped or retarded by the resistance of the circumambient medium, that there seems to be no better method of accounting for it than by deriving it immediately from such a resistance. The fire diverging from the points strikes upon the adjacent air; while the air, reacting against the streams of fire, or *resist-*

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ing them, gives a retrograde motion to the points of the wire; just as a chair, if placed upon casters, will run backwards, when the person sitting in it pushes against the wall with a stick. If the wall were out of his reach, his stretching out the stick would make no impression upon the chair: and the streams of fire will be equally insufficient to produce a motion in this machine, if there be no *air* within the sphere of their activity. To prove this, I made the three following experiments.

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Exp. III.

In order to try whether the fire, moving *horizontally* in the exhausted receiver, would have any better effect; I placed a ring of brass wire within the vessel, and fixed it at such an height, that it coincided with the plane of the intended motion. The machine being again electrified under these circumstances, the fire did now appear to issue horizontally from the points toward the brass ring, and thence it went down to the plate at the bottom, by means of some other small wires added for that purpose. But notwithstanding all this, the points of the machine were stationary.

Reflections.

I. The streams of fire do not fall down to the plate by their *gravity*, as two streams of water might be made to do from two orifices in the ends of a small horizontal pipe; for then the velocity with which they issue from the points should occasion them to describe a *parabola*, whereas they describe two straight lines; therefore they are carried down, not by the force of gravity, but by a pressure of another kind which operates in what we call a vacuum.

II. As the rays of the electric æther do not pass off from the points in a conical form when the machine is placed in vacuo, but in a perpendicular line; it is certain that the particles of fire do not *recede* from each other so much when the air is absent, as when it is present; therefore they do not recede from one another by any inherent *repulsive power*: for were they indued with such a power, they would be more at liberty to exert it when the pressure of the atmosphere is taken away, and ought to diverge *most* where they are found by experiment to diverge *least*, that is, in an exhausted receiver.

III. The continuance of motion in any space

space doth not infer the necessity of a vacuum. The contrary to this is so true, that a variety of motions may be exhibited, for the producing of which, the presence of a resisting medium is absolutely requisite. We have one instance of it in this experiment; and as the analogy I would here point out to the reader is a thing of no small moment, let me desire him to consider attentively with himself, that if the *glass globe*, which we here make use of as a promptuary or fountain-head of elementary fire, were to send forth its store in the ordinary course of nature, as the *globe of the sun* doth send forth its light; the motion of this machine would be perpetual, not only in theory, but in practice.

The same may be said of the revolution of the two lamps, in the instrument described at *p.* 68: for the motion of those lamps would be perpetual, were their light as perpetual as that of the sun is.

There is another experiment, which I have frequently performed with much pleasure, and never without exciting some degree of admiration in those who have beheld it. A small light bubble of glass being laid on a polished plate of metal, upon which a brass ring (of about half a foot in diameter) is so

placed

placed as to be conveniently electrified without electrifying the plate at the same time; the little sphere of glass will describe an orbit about the ring, and will turn at the same time about its own axis, the poles of its rotation being nearly at right angles to the plane of its orbit. Here again, if the emission of light from the electrical globe were as constant as the supplies from the sun to the planets, the motion of this sphere would resemble the motion of the earth, as nearly in its perpetuity, as it doth in some other respects.

In all these instances, a resisting medium does not hinder motion, but actually promotes it, and is one of the immediate causes of it; and, were these little experiments as adequate to the greater phænomena of the universe as they are analogous to them, would render the motion perpetual. An hypothetical train of reasoning might lead us to conclude, that if less matter were in the space, the motion would be more free, and continue much longer: upon the supposed strength of which conclusion, (if a little geometry were interwoven with it,) we might think it necessary to get rid of the *air* and of *all sensible matter;* and then we should

should also get rid of the causes of motion. In a word, the facts now before us shew how much we should lose by the application of this unphilosophical method; which would promote the success of these experiments, just as much as we should enable a man to run faster, were we to rid him of the incumbrance of his boots and spurs by cutting off his legs.

I think it hardly necessary to observe, as the thing is so obvious, that although the mode of operation in each of these experiments is very different, yet the effects in all of them are deducible from the same causes, fire and air, ordained in a wonderful manner to co-operate with each other.

On Chap. VI.

Page 76, l. 14. &c. It hath been hinted to me by a learned friend who saw this chapter in manuscript, that the geometrical argument of Dr. Keil, though it makes but an indifferent figure in the manner he hath stated it, may nevertheless be applied to demonstrate an *interstitial vacuum* between the parts of bodies. And thus much indeed it may warrant us to affirm, that if the world is filled with an homogeneous matter, all the particles

particles of which are exact spheres, of equal sizes, and all of them in contact; an interstitial vacuum must be the consequence: and the ratio of the full space to the empty space, will be as the solid content of a sphere to the difference between that and the content of a cube of the same diameter. But then, how many suppositions is it necessary to make, before the way is clear to such a conclusion? and when we have attained it, it leaves my argument but where it found it. For unless these homogeneous spheres are *out of contact,* (the contrary to which is supposed in the demonstration,) a motion propagated amongst them will be *mechanical;* and that is all I am contending for. But such mathematical reasonings are all of them wide of the purpose, only tempting us to ramble from the real merits of the cause, and to multiply words without knowledge; an observation which ought to be as freely applied to what I have hitherto said in answer to the demonstration, as to the demonstration itself. If we leave geometry to take its chance, and make a transition to reason and observation, it will be hard enough to shew, that within the whole created system of the world there is any space capable of holding

a particle of matter, which has not such a particle in it. A subtile substance, (that of fire or light,) not to be excluded by the surfaces of the most solid body, is in perpetual agitation, and ready, as experience teaches, to find its way into every channel capable of receiving it. It has likewise been proved above, that between the particles of this substance there is no *repulsive power* to keep them at a distance from each other: and as Sir Isaac Newton hath given us some fine experiments in his *Treatise of Optics*, whence it is highly probable that even the particles of light are of various sizes, they will on that account fill up any given space the more completely; and the interstitial vacuities, if they can be called such, will vanish into something not worth regarding, because it is impossible to be conceived, unless the imagination should put a trick upon itself; which, I believe, is sometimes the case, when it is contemplating such objects as are beyond its reach. If we keep within the limits of our understanding, and attend to nature itself as it is displayed before our eyes, we may express both safely and truly all that is necessary to be affirmed upon this occasion, in the following words, taken from the

the discourse of Timæus Locrus the Pythagorean—Πυρ μαν ων δια ταν λεπτομερειαν δια παντων ηκει, αηρ τε δια των αλλων εξω πυρος· υδωρ δε δια τας γας. Απαντα δ'ων πληρη εντι, ουδεν κενεον απολιποντα—"*Fire, by reason of* "*its subtilty, penetrates into all things; air,* "*into all the other elements, except fire;* "*and water into earth: so that the world* "*is full of matter, and there is no vacuum* "*left in it.*" N. B. This discourse is subjoined to Plato's Timæus; or it may be found in Gale's Opuscula Mythologica.

On BOOK III. CHAP. II.

An Addition to the Note *at* Page 207.

AS I have here dropped an hint concerning the *danger* which is to be apprehended from *electricity*; it may not be amiss to give some short account of its *good effects*, so far as they have fallen under my own observation.

A girl of about 12 years of age, the daughter of a shepherd in this parish of Wadenho in

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it was now visible enough, that the two streams, instead of passing off from the points in the form of a conical brush of rays, with its axis parallel to the horizon, went perpendicularly downwards in two parallel lines to the brass plate of the air-pump: and it was utterly impossible that the fire thus perpendicularly directed (had there been no other reason for it) should occasion an horizontal motion in the machine.

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The same may be said of the revolution of the two lamps, in the instrument described at *p.* 68: for the motion of those lamps would be perpetual, were their light as perpetual as that of the sun is.

There is another experiment, which I have frequently performed with much pleasure, and never without exciting some degree of admiration in those who have beheld it. A small light bubble of glass being laid on a polished plate of metal, upon which a brass ring (of about half a foot in diameter) is so placed

placed as to be conveniently electrified without electrifying the plate at the same time; the little sphere of glass will describe an orbit about the ring, and will turn at the same time about its own axis, the poles of its rotation being nearly at right angles to the plane of its orbit. Here again, if the emission of light from the electrical globe were as constant as the supplies from the sun to the planets, the motion of this sphere would resemble the motion of the earth, as nearly in its perpetuity, as it doth in some other respects.

In all these instances, a resisting medium does not hinder motion, but actually promotes it, and is one of the immediate causes of it; and, were these little experiments as adequate to the greater phænomena of the universe as they are analogous to them, would render the motion perpetual. An hypothetical train of reasoning might lead us to conclude, that if less matter were in the space, the motion would be more free, and continue much longer: upon the supposed strength of which conclusion, (if a little geometry were interwoven with it,) we might think it necessary to get rid of the *air* and of *all sensible matter;* and then we

 should

should also get rid of the causes of motion. In a word, the facts now before us shew how much we should lose by the application of this unphilosophical method; which would promote the success of these experiments, just as much as we should enable a man to run faster, were we to rid him of the incumbrance of his boots and spurs by cutting off his legs.

I think it hardly necessary to observe, as the thing is so obvious, that although the mode of operation in each of these experiments is very different, yet the effects in all of them are deducible from the same causes, fire and air, ordained in a wonderful manner to co-operate with each other.

On Chap. VI.

Page 76, l. 14. &c. It hath been hinted to me, by a learned friend who saw this chapter in manuscript, that the geometrical argument of Dr. Keil, though it makes but an indifferent figure in the manner he hath stated it, may nevertheless be applied to demonstrate an *interstitial vacuum* between the parts of bodies. And thus much indeed it may warrant us to affirm, that if the world is filled with an homogeneous matter, all the particles

particles of which are exact spheres, of equal sizes, and all of them in contact; an interstitial vacuum must be the consequence: and the ratio of the full space to the empty space, will be as the solid content of a sphere to the difference between that and the content of a cube of the same diameter. But then, how many suppositions is it necessary to make, before the way is clear to such a conclusion? and when we have attained it, it leaves my argument but where it found it. For unless these homogeneous spheres are *out of contact,* (the contrary to which is supposed in the demonstration,) a motion propagated amongst them will be *mechanical;* and that is all I am contending for. But such mathematical reasonings are all of them wide of the purpose, only tempting us to ramble from the real merits of the cause, and to multiply words without knowledge; an observation which ought to be as freely applied to what I have hitherto said in answer to the demonstration, as to the demonstration itself. If we leave geometry to take its chance, and make a transition to reason and observation, it will be hard enough to shew, that within the whole created system of the world there is any space capable of holding

a particle of matter, which has not such a particle in it. A subtile substance, (that of fire or light,) not to be excluded by the surfaces of the most solid body, is in perpetual agitation, and ready, as experience teaches, to find its way into every channel capable of receiving it. It has likewise been proved above, that between the particles of this substance there is no *repulsive power* to keep them at a distance from each other: and as Sir Isaac Newton hath given us some fine experiments in his *Treatise of Optics*, whence it is highly probable that even the particles of light are of various sizes, they will on that account fill up any given space the more completely; and the interstitial vacuities, if they can be called such, will vanish into something not worth regarding, because it is impossible to be conceived, unless the imagination should put a trick upon itself; which, I believe, is sometimes the case, when it is contemplating such objects as are beyond its reach. If we keep within the limits of our understanding, and attend to nature itself as it is displayed before our eyes, we may express both safely and truly all that is necessary to be affirmed upon this occasion, in the following words, taken from the

the discourse of Timæus Locrus the Pythagorean—Πυρ μεν ων δια ταν λεπτομερειαν δια παντων ηκει, αηρ τε δια των αλλων εξω πυρος, υδωρ δε δια τας γας. Απαντα δ' ων πληρη εντι, ουδεν κενεον απολιποντα—"*Fire, by reason of* "*its subtilty, penetrates into all things; air,* "*into all the other elements, except fire;* "*and water into earth: so that the world* "*is full of matter, and there is no vacuum* "*left in it.*" N. B. This discourse is subjoined to Plato's Timæus; or it may be found in Gale's Opuscula Mythologica.

On BOOK III. CHAP. II.

An Addition to the Note *at* Page 207.

As I have here dropped an hint concerning the *danger* which is to be apprehended from *electricity*; it may not be amiss to give some short account of its *good effects*, so far as they have fallen under my own observation.

A girl of about 12 years of age, the daughter of a shepherd in this parish of Wadenho in

 North-

On Chapter V.

Page 68, l. 4. Some other motions like to that of the two lamps may be contrived in a different manner. Fix a needle upon a pillar of glass or sealing wax four or five inches in length, and place a small wire upon it, pointed at each end, and bent into the shape expressed by *fig.* 2. of *plate* I. Let this little machine be so placed, that you can electrify the brass cap in its centre by sparks from a wire hanging perpendicularly over it, but not touching it. If the instrument is well made, and the fire strongly communicated, the wire will turn upon its centre as fast as the flyers of a common jack: and if the room be darkened, you will see a ring of light formed by the electric æther as it streams from the points of the wire.

This motion is so far from being stopped or retarded by the resistance of the circumambient medium, that there seems to be no better method of accounting for it than by deriving it immediately from such a resistance. The fire diverging from the points strikes upon the adjacent air; while the air, reacting against the streams of fire, or *resist-*

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ing them, gives a retrograde motion to the points of the wire; just as a chair, if placed upon casters, will run backwards, when the person sitting in it pushes against the wall with a stick. If the wall were out of his reach, his stretching out the stick would make no impression upon the chair: and the streams of fire will be equally insufficient to produce a motion in this machine, if there be no *air* within the sphere of their activity. To prove this, I made the three following experiments.

Experiment I.

I set the machine upon the plate of my air-pump; and having covered it with a large receiver, electrified it by means of a wire passing down to it through a collar of leathers. While the receiver remained full of air, the machine made its revolutions as well within the glass as it had done before in the open air.

Exp. II.

The same trial being made when the receiver was exhausted, no motion ensued. The room being made dark, the operation of the electrical machine was continued: and

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operation. There was likewise a copious discharge from the blister, which for some days before had produced no effect, and was in a manner dried up.

After the *second* operation she continued to mend. After the *fourth*, she went by herself upon crutches to a neighbour's house at some little distance. At this time the shocks began to hurt her so much as to make her shed tears; a plain proof that her limbs had now in a great measure recovered their sensibility.

After the *sixth* operation, she was able to walk up a steep hill to church, without any assistance even from a walking-stick: and during this whole course, no medicines of any kind were administered. Some weakness did still remain, which electricity would not remove; therefore I recommended the use of the cold bath, by the help of which she soon recovered her strength, and is now able to work for a livelihood nearly as well as before, except that her leg on the right side is somewhat shorter than the other, which, as she walks, does necessarily occasion her to sink a little on that side.

After a time, she was much troubled with an inflammation in her eyes; and there appeared

peared to be some violent humours afloat in the habit, owing (as I suppose) to a translation of the morbid matter from the nerves to the blood-vessels, I had recourse to some of the methods commonly applied to upon such occasions: and though the humour in her eyes is not absolutely cured, it is so far corrected as to give but little trouble, and I think she will by degrees entirely get the better of it.

As this case seems to be a remarkable one, I have given a circumstantial account of it; and the reader may depend upon the truth of all the particulars, none of which (to the best of my knowledge) are in any degree disguised or exaggerated.

I have had other opportunities of trying the power of electricity: and though it ought not to be hastily cried up as a cure for all diseases, which hath been the misfortune of many an useful remedy, some there certainly are to which it may be applied with a prospect of success; and I could be glad to see its usefulness properly ascertained, and discreetly limited, by some candid and judicious gentleman of the faculty. From what has appeared to me within my own little sphere, I believe it may be of much service

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in pains of the *rheumatism*, and *paralytic affections*, where they are recent, and the patient not too far advanced in years. Some of the principal disorders arising from *obstructions* might find great help from it, if they are taken in time: and it might be worth while to try whether it would not stop the progress of a *gutta serena*, or of any other disorder that may be referred to this class, which is a very numerous one. For experience teaches, that it will put the matter of the disease in motion, and powerfully promote a diaphoresis; but it may require the skill of a regular physician, and some auxiliaries from medicine, to clear the body properly of the disease, and bring it to an happy issue.

Its greatest efficacy, I think, will be found in removing (and that in a very small space of time) all spasms or cramps, particularly such as proceed from any sudden *cold* upon the external parts. And it seems highly probable, that, in the most extreme cases of this kind, immediate relief might be expected from it, even in that dreadful spasm which affects the muscles of the back or breast, and is so common both in the East and West Indies. Bontius, in his Hist. Nat. & Med. Ind.

Ind. Orient. p. 18. gives this description of it:—*Tam repentinus & subitus est aliquando ejus impetus,* &c. *This disease is sometimes so sudden and violent, that men are seized with it in a moment, and become as rigid as a statue; the muscles in the anterior or posterior part of the body being contracted towards their origin; by which means the patient is bent either backward or forward, and fixed in one posture or the other, as the affected muscles are situated. A shocking distemper this is indeed! which in the space of four-and-twenty hours will carry off those who are afflicted with it in extreme agony, while the internal or vital parts are perfectly sound, and in their natural state. The misery of these poor creatures has a ghastly effect upon their countenances; especially if the disorder be attended (as it frequently is) with the* cynic spasm or dog-like convulsion, *by which both the cheeks are drawn aside toward the ears. The face is red, the eyes are livid, the teeth grate together; and instead of their natural voice, they utter a strange noise, as if they were speaking from a cave under the ground: insomuch that persons unacquainted with the case would actually take them for dæmoniacs.*

Piso, who has written a Natural History of the

the West-Indies, tells us the disease is generally owing to this cause—*quod interdiu madidi ac sudore æstuantes, ab ingruente nocturno frigore sibi non cavent*—" that they who have " been thrown into violent sweats by the heat " and labour of the day, will afterwards too " carelessly expose themselves to the cold air " of the night." He observes likewise, that on some occasions the teeth are closed so fast, that it is necessary to break open the mouth with a probe of iron; and when this is done, the patient is perhaps utterly incapable of swallowing; so that nothing can be administered by the mouth to give him any help.

That an electrical operation might remove the cause even of this distemper, how frightful soever its symptoms may be, I was induced to believe, first, by the following accident. A few months ago, one of my maid-servants, by taking some cold in the night, arose in the morning with that spasm which is commonly called a *crick* in the neck; so violent, that her head was drawn aside toward one shoulder, and could not be stirred any way without causing an acute pain. I ordered her to place herself upon a stand supported by feet of glass, with a design

sign to electrify her; and desired a person present to draw sparks with a finger from the point where the greatest pain was felt when she attempted to move her head. By this means, in a minute or two, her head came nearer to the perpendicular, and, by continuing the operation, was very soon restored to its natural position. Some soreness remained in the part; but that was easily removed by keeping her neck warm. All the sparks that were drawn upon this occasion raised so many little red pustules or blisters; which I think is not usual if the part be in an healthy state.

This complaint, though less in degree, is the same *in specie* with that above-mentioned; and is sometimes of bad consequence, as it hath been known to be fixed upon a person for several years by being improperly treated at first. Now if electricity can give such immediate relief in one of these cases, much might be expected from it in the other. And the probability of this will farther appear, if we consider the ordinary methods of cure, which are the same in intention with those prescribed by Hippocrates, and these are, bleeding, friction, sudorifics, (if they can be administered,) and anointing the

patient externally with the essential aromatic oils, as of cloves, mace, oil of turpentine, &c. for these oils are but so many vehicles of elementary fire. And would not the agent itself, unincumbered with the vehicle, and passing instantaneously through all the most minute ducts of the part affected, produce the desired effect with much greater speed and efficacy with less trouble and equal safety?

The force of the electrical fire is principally exerted upon the *nerves* and *tendons* of the body: whence there is reason enough to believe, that this fluid is the same with that *something* which learned physicians have so much discoursed upon under the name of *animal spirits*. The nerves do not appear as if they were designed to admit within them any animal fluid or liquor, unless it be an indolent lymph which is necessary to keep them moist: but their pellucidity indicates that they are properly adapted to give a direct passage to the fluid of *light*; for they are transparent, and that not transversely, but longitudinally, or in the direction of their fibres. I once observed this accidentally, as some eyes of sheep and oxen, which I had procured in order to dissect them, were lying before

before me upon my table. One of these eyes *shone* in the day-time, much in the same manner as the eyes of some animals do in the dark. Not being able to account for this, I endeavoured to examine the fact as narrowly as I could; and at length perceived, that if my hand were interposed between the nearest window and the extremity of the optic nerve, (a part of which, nearly an inch in length, remained with the eye, and was accidentally pointed toward the window,) the light immediately disappeared.

This led me to consider, whether the light that appears in the eyes of some animals in the night-time is really a *reflexion* of light from the eye, as is commonly supposed; or whether it does not rather pass into the eye, through the optic nerve, from the body of the animal? Dr. Willis calls it *jubar insitum*; and, for my own part, I cannot conceive how this shining can be occasioned by a reflexion of light from the *choroides* in the bottom of the eye, when the light to be reflected (as in a dark night) is not visible before its entrance into the eye.

If a candle be held before the eyes of a dog, and you place yourself in the line of reflexion, the light will be visibly reflected from

from his eyes, because the illumination is sufficiently strong: but when there is no visible illumination at all, how should it account for the like effect? whence it is more reasonable that this appearance should be owing to a light from within the body of the animal, which being weaker than the light of the day, but stronger than the light of the night, is visible in the night and not in the day. The light of those other bodies which shine in the dark, is inherent in the bodies themselves; as in putrifying veal, fish, rotten wood, phosphorus, the glow-worm, &c. concerning the last of which, that eminent anatomist and philosopher, T. Bartholine, hath this observation—*Habent illæ (cicindelæ) si examinentur, lucidum humorem in posteriore parte corpusculi, ubi cor latet, quo movetur cor & illuminatur, tamdiu splendore suo relucentem, quamdiu cor vivit & movetur. Si tam patulum oculis nostris esset pectus animalium, quam cicindelæ transparens corpusculum, forsan non absimile lumen in corde appareret, quod extinguitur quamprimum externo aeri patet*, &c. "*If a glow-worm be examined, it will appear to have a lucid liquor in the hinder part of its body, where the heart is placed, by which the heart is moved and illumi-*

"*illuminated; and this fluid retains its light, "so long as the heart of the insect retains its "life and motion. Were the breasts of ani- "mals as pervious to the sight as the transpa- "rent body of the glow-worm, perhaps a light, "analogous to this, might appear about the "region of the heart, which light is extin- "guished the moment it is exposed to the open "air.*" T. Barthol. Epist. de Flammulâ Cordis. p. 4.

On Chap. III.

An Addition to the Note *at page* 232—233.

Speaking of the *force* that is exerted in the experiments on *artificial freezing*, I have called it a force which *art would find it difficult to measure.* Such I then imagined it to be, and contented myself with relating an experiment, from which it could only be guessed at in the grossest manner. But being desirous of obtaining some certainty in an affair which deserves a deeper examination, I con-

trived a way, this last winter, of measuring this force to a sufficient degree of exactness.

I made use of the *box* already described in the foregoing part of this note. It was filled, as before, with water purged of its *air*; and being covered, but not screwed down, it was placed upon an oaken pedestal, which had for its base a flat hewn stone of about a foot square. The shorter arm of a very strong lever was made to press upon the top of it; and this lever was compounded with two others, by which the power of it was greatly increased. At the extremity of the longer arm of the most remote lever, a cord was fastened, which ran over a pulley, and had a weight of 28lb. hanging at the end of it. This weight, acting as a *mechanical power*, made the shorter arm of the first-mentioned lever press down the cover of the box with a certain force, which, according to the general law of all mechanics, was to the 28lb. at the end of the line, *as the space moved through by the power, to the space moved through in the same time by the weight*: but these spaces being compared with each other, I found that the greater was to the lesser as 82 to 1. So that if we multiply 28 by 82 the product

product will be 2296 lb. to which something must be added for the friction of the machine, though I took what care I could to render its motion as true and easy as possible. While the cover of the box was pressed down by so great a weight, the water inclosed within it was made to freeze; and the agent by which the water was congealed, did fairly overcome the whole force of the machine.

Though this experiment succeeded so far as to give me the satisfaction I wanted, it was interrupted by an accident I did not look for. When the water began to freeze, and the cover of the box to be raised up from the rim, I perceived that the ground yielded under the pressure, and that the flat stone which served as a basis to the pedestal was sunk a little below its first position. By this means the force was at first spent upon the ground, and did not take place in the machine till the ground would no longer give way. It was, however, so sensibly perceived in the machine likewise, as to prove that this force was at least superior to *one ton two hundred and ninety-six pounds.* How much greater it may prove to be, I cannot as yet affirm; though I believe my apparatus would answer

the purpose if it were required to pursue the experiment to the bottom. But there are so many circumstances to be nicely attended to in order to make it succeed, and so much time and trouble to be bestowed upon it out of doors in cold weather, that my patience was wearied out, for this winter at least, by a single attempt.

The cavity of the box, as I find by gauging it, contains 5 cubic inches and $\frac{6}{10}$. Water, when it freezes, commonly increases in its bulk by $\frac{1}{9}$ of the whole: therefore the space occupied by the æther, which exerted all this force upon the machine, was equal only to about $\frac{6}{10}$ of a cubic inch. And hence it will appear, by a calculation not worth particularizing, that the force of this æther (even in this experiment, which undoubtedly falls very far short of the whole truth,) was about *two hundred and seventy-three times greater than the ordinary pressure of the atmosphere.*

Mr. B. Robins, the engineer, found, by several accurate experiments, that the force of fired gunpowder is about 1000 times greater than the pressure of the atmosphere: and the force of that agent which consolidates water into ice, may be found equal to it,

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for ought that has yet appeared to the contrary. We do not wonder at the power of fire, when it acts with a vehement degree of *heat*, although its effects are so great that nothing can withstand it, as in gunpowder, and in the engine for draining mines by the steam of boiling water. But here we have the same substance (for the water was perfectly cleared of its *air)* exerting a most astonishing force, even when reduced to the temperature of *ice;* and we may judge from the phænomena of *cohering bodies*, that this force will be greatest when the cold is greatest.

The expansion occasioned by heat, and this expansion of water by frost, are certainly not to be accounted for in the same manner. My own opinion, which I readily submit to the judgment of others, is this— that the force of *heat* arises from a vehement *motion*, and vibration of the particles of fire; whereas this *cold force*, like the shock in electricity, doth not proceed from elementary fire as it gives heat, but as it *restores an equilibrium* which by some means hath been interrupted.

This distinction I would support, by giving an instance of something similar to it

in the element of air, which acts in two several capacities, *viz.* as *wind,* and as *sound,* corresponding respectively with those two different operations of fire. *Sound* arises from a *vibration* or *undulatory motion* of the parts of air; whereas *wind* rushes into a more rarefied space to *restore an equilibrium*: and, what is very wonderful, and very true, though it be hard enough to conceive, these two operations will either meet or cross without disturbing one another. If a great gun be fired two or three miles off to the *eastward,* and the wind blows hard at the same time from the *westward,* the sound will arrive in the same space of time as if its motion had concurred with the motion of the wind. In some degree, the same thing is observable even in such a fluid as water; one stream of which, if it moves swiftly over a smooth bottom, will cross many others nearly at the same angle, and appear to have suffered little or nothing from them, as I have frequently observed with some surprise.

These considerations will enable us to see in a proper light the following experiment, to which I have alluded at page 203. l. 21. though I did not think it necessary to mention it in that place.

If

If an iron bar of some length be heated red hot in the middle, and you electrify it at one end, a spark of the electric æther may be drawn from the other. Such philosophers as do not carefully distinguish between the motions of fluids and those of solid masses, will ask us how this can be, if fire and the electric æther are supposed to be the same thing? Here is elementary fire going off in a stream at right angles to the axis of the bar; while the electric æther can go straight from one end to the other, without being absorbed, dissipated, and carried off in the common stream at the place which is red hot, or without being *obstructed in its passage by a fluid of the same kind, as there is reason to believe it would be.* But indeed there is not the least reason to believe this, as the parallel now before us will plainly demonstrate. For when a cannon is fired off, the air is thrown into subtile waves, spreading themselves very swiftly throughout a circular space, of which the sonorous body is the centre. But a strong wind will blow across this space, even through the centre of it, without being stopped itself, and without retarding the motion of the sound. How unphilosophical would it be to argue from

this observation, that the element which brings sound to the ear, and the air which blows across it as a wind, are two different fluids? Who will venture to say, that the current of wind or the waves of sound ought to be *obstructed by a fluid of the same kind,* seeing all this is false by experience? And if in the *air* two such effects can be produced without any considerable disturbance, and may consist well with each other, though they are apparently opposite and inconsistent; how much more will they consist in the element of *fire,* the subtilty of which will admit of a greater variety of motions, all of them more perfect in their kind, as fire is more subtile than air.

This experiment may also be rightly understood only by considering what effect the *pressure of the air* will have on the surface of the iron bar. For if the part that is red-hot could by any contrivance be included in a space exhausted of air, the fire would be dissipated, and the bar would grow cold much sooner there than in the open air. Now the same pressure which will suffer the fire to escape but slowly, and in a certain surplusage, under the form of *heat,* doth also suppress and keep in the *electrical cur-*

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rent, so that it shall go freely from one end of the bar to the other without being dissipated; whereas this, together with the heat, would be dissipated *in an exhausted space as fast as it could be infused.*

On Book IV. Chap. I.

Page 282. line 13. &c. Men of learning have been divided in their sentiments concerning the optical knowledge of the ancients. Some are so swallowed up by an admiration of the discoveries that have been made in the last and in the present century, that they are tempted to pass sentence upon the skill of the ancients, before they know what the ancients have said for themselves; and they imagine there is absolutely nothing to be said on the opposite side of the question but what arises from an irrational attachment to the wisdom of antiquity. But, seting apart all prejudice to one side or the other, I shall humbly offer a few short hints, only as an encouragement to some farther examination of the subject, by those who have learning and leisure enough to undertake it.

That

That the ancients were acquainted with the *burning* power of *mirrors* and *glasses*, is not disputed. M. Buffon of Paris contrived a method, some few years ago, of setting deal boards on fire by the reflected rays of the sun, at the distance of 200 feet, merely by a proper application of a number of plain looking-glasses: an experiment which did in a great measure re-establish the credit of what has been reported of Archimedes burning the ships of the Romans at a considerable distance from the walls of Syracuse. See *Phil. Transact.* No. 483. But although burning-glasses were known to the ancients, the moderns have denied that they did ever observe the power of glass in *magnifying* objects, affirming that not the least hint of such a thing is to be found in any of their writings. How they could be possessed of the art of glass, and make a daily use of glass vessels of all sorts, without observing that objects appear larger through glass that hath a spherical surface, would to me, I confess, be hard enough to conceive, though there were not a single passage of antiquity that made any mention of it. But that the ancients did actually observe this, is clear from their own accounts. Seneca has these words—

words—*Poma per vitrum aspicientibus multo majora sunt*—or, as he expresses it in another part of the same book—*si innatant vitro*—"apples appear *greatly magnified* to those "who view them as they swim in a vessel "of *glass*." *Nat. Quæst. lib. I. cap.* 6. This observation, it may be said, if they went no farther, could not be applied to any use; the advantage that might be obtained by immerging the leaf of a book into a vessel of water, in order to see the letters somewhat magnified, would never be worth the trouble. To read small letters with any tolerable convenience, either a portion of a sphere of solid glass, or an hollow sphere of glass filled with water, must be placed between the object and the eye of the spectator. The latter of these they certainly had in use, and applied them as *dioptric* burning-glasses. That they could do this, and be ignorant of their magnifying power, would not be credible; and the contrary is plainly affirmed. Seneca observes—*Literæ, quamvis minutæ & obscuræ, per vitream pilam aquâ plenam, majores clarioresque cernuntur.*—"Letters, though minute and obscure, ap-"pear larger and clearer through a glass "bubble filled with water." *Ibid. cap.* 7. It

It is scarce probable that any curious mathematician, of whom there were many among the ancients, should have been familiar with so important an experiment without going farther: but how could this be done, unless they understood the way of *grinding* glass, so as to form it into portions of larger spheres? *To do this* (says Dr. Hook) *they must have known how to have wrought and ground their glasses, as we do; whereas in all probability the ancients knew only how to blow their glasses and make vessels of it.* See Dr. Smith's Optics. Vol. II. p. 16. Art. 94 of the Remarks. But here Dr. Hook was under a mistake; for the ancients gave a figure to their glass, not by blowing only, as he has imagined, but by the three different methods in use with the moderns. Pliny describes the practice of the ancient artists in these words—*Aliud flatu figuratur, aliud TORNO TERITUR, aliud argenti modo cœlatur, Sidone quondam iis officinis nobili, siquidem etiam specula excogitaverat. Hæc fuit ANTIQUA RATIO VITRI.*—"Some glass is fashioned by blowing; some "is ground upon a wheel, or in a turning-"lath; and some is engraved like silver. "Sidon was celebrated for his glass-works, "having

"having also invented *specula*. Such was "the ancient art of glass." *Nat. Hist. lib.* 36. *cap.* 26. In another place, Pliny calls this city of the Phœnicians—*Sidon artifex vitri. Lib.* 5. *cap.* 20. As to the words—*siquidem etiam specula excogitaverat*—I quote them as they stand in the text of the *variorum* edition; but the sense of the author is not clear. He may possibly mean more than we should expect: *specula* is a proper word to signify *telescopes;* and *excogitaverat* must allude to some notable *invention*. But as we may sift out of a dark expression more than the author himself understood by it, I dare not lay any great stress upon it.

That glass was *ground* by the ancients, may be proved from the writings of Seneca; for, how could a *prism* of glass be made by *blowing?* Yet such things were in use among the *virtuosi* of Rome in the days of Nero—*Virgula solet fieri vitreæ—pluribus angulis—hæc si ex transverso solem accipit, colorem talem, qualis in* arcu *videri solet, reddit.* "A rod or bar of glass (saith Seneca) is "made, with several angles, which, if it "receives the rays of the sun through it, "makes such colours as we see in the *rain-* "*bow.*" Nat. Quest. lib. 1. cap. 7. And

he

he speaks of *multiplying* glasses, the several faces of which must undoubtedly have been cut upon a wheel. *Si aptè fabricata foret, totidem redderet soles, quot habuisset insecturas.* Ibid.—But there is one observation I ought not to omit, *viz.* that although Seneca speaks so expressly of the use of glasses, and mentions the *refraction of an oar in the water*, he does not seem to have any idea of the *principles* upon which these effects are brought to pass.

Spectacles are supposed to have been first known about the latter end of the 13th century: but there is little doubt to be made that our famous countryman Friar Bacon was acquainted both with spectacles and telescopes before that time. Upon any other supposition, his own expressions on the subject are altogether unaccountable. And I am inclined to believe, that some traces may be found of an earlier date. Amongst the *adages* of Junius (published in the same volume with those of Erasmus) this short passage is extracted from Pisidas, a *Christian* writer, who flourished at Constantinople in the 7th century—Τα μελλοντα ως δια διοπτρου βλεπεις, "you see things future as by a "*dioptrum.*" What can this *dioptrum* be?

 Must

Must we not understand by it either a *spectacle-glass*, or a *prospective-glass*? We know of no other instruments whereby things indistinct and at a distance may be seen as if they were near at hand. The art by which this is brought to pass, is plainly the subject matter of the simile. The author, (Junius,) in whom I accidentally met with this passage, being himself ignorant of the telescope, takes this dioptrum for the *sights* of a quadrant, or some other geometrical instrument. But how can these sights (unless they are *telescopic* ones) afford any resemblance to that prophetical sagacity in the mind, whereby it sees things as yet at a distance; to which nothing in the world can be so nearly like, as that power of seeing distant objects by the help of optical glasses? As to the *plain sights* of a quadrant, &c. the eye is so far from being assisted by them, when it views a distant object, that the chief difficulty an artist has to contend with, is that of making the accuracy of the line of collimation upon the instrument consist with clear and distinct vision.

It may seem strange, indeed, that if *dioptric glasses* were anciently in use, we should hear of them no oftener in the writings of the ancients. This may be hard to account

for;

for; and yet it may be very unsafe to draw a positive conclusion from negative evidence. Friar Bacon mentions the refractions of the sun's rays through a glass sphere: but as he does not say *totidem verbis* that he ever viewed an object through such a sphere, the learned Dr. Smith is of opinion (if I do not misunderstand him) that he had no experience of its *magnifying* power. See Optics. Vol. II. p. 21. R. And had Seneca described his glass ball filled with water only as a burning glass, this might have tempted us to argue that he knew nothing of its use in *magnifying letters*: only he happens to have precluded such a conjecture by declaring the contrary. He might know more than he has spoken of: the mathematicians and workers in glass of those days might know more than he did: and the ancient Greeks and Phœnicians might know more than the Latins: but the accounts we have of many ancient works of art are so much broken by the injuries of time, the ambiguities of language, the succeeding interests of different sects of philosophers, and the barbarism of the intermediate ages, that it must now be very difficult to establish this supposition by so many and clear proofs as ought to be deemed satisfactory.

If

If we should argue *by inference*, the case will be a little altered. The cabinets of the curious are said to contain some very ancient gems of admirable workmanship, the figures upon which are so small, that they appear beautiful through a magnifying glass, but altogether indistinct and confused to the naked eye. And if they cannot be viewed, how could they be wrought without the assistance of glasses? How could it be known, that the moon has a form like to that of the earth; that it has plains, hills, and vallies in it? When it is seen through a telescope, the disposition of the lights and shadows render this very evident upon the common rules of perspective; but no such thing appears to the naked eye. How could it be known, that the *via lactea* arises from the combined rays of an infinite number of small stars? How came the true solar system to have been so well known and described by the most eminent philosophers of antiquity; when the best, and indeed the only decisive proofs of it, must be derived from the telescope? But, above all, how came it to be asserted (as we have already seen at p. 289) that *the sphere of the fixed stars is so immense, that the circle of the earth's annual orb bears no greater a propor-*

tion to it than the centre of any sphere bears to its whole surface? This does so far exceed the comprehension of the human mind, that it is now the most indigestible truth in the modern astronomy; and never was asserted since the revival of the Pythagorean scheme, till Dr. Bradley, by a course of the most accurate observations that ever were made with a *telescopic apparatus*, reduced the *annual parallax* of the fixt stars to an insensible quantity.

Many ingenious men, and some good mathematicians who never descended to the practical part of astronomy, are ready to suspect the truth of all such conclusions in the science as depend upon the measuring of angles to a very few *second* minutes of a degree. But, for my own part, though I would not be bound to follow the *speculations* of every modern astronomer, I am not disposed to question the truth of any astronomical discoveries pretended to by so great a master of the science as Dr. Bradley, furnished as he is too with the finest instruments in the world: and I think I can guess very nearly at the degree of exactness that may be attained, by what I have been able to learn in this way from my own experience. I bestowed some pains in contriving

ing and executing an instrument of a large radius, with telescopic sights, &c. which in the many observations I have made with it, has far exceeded my first expectations. In June 1761, I had an opportunity (which I had long desired) of observing the *obliquity of the ecliptic*; and knew I could so far depend upon the observation, when compared with that of Mr. Flamsteed and some others, as to be morally certain that this obliquity is not so great at present, by about *one minute* of a degree, as it was an hundred years ago. I transmitted the result of my observation to a learned gentleman, eminently skilled in astronomical studies, who has very lately informed me, that it differs only 2″ from the obliquity at that time as determined by Dr. Bradley.

These few reflexions on the optical knowledge of the ancients I have thrown hastily together, merely as an essay, to be carried farther (if it is worth it) by those who are more advantageously situated for such an employment. My reading is so circumscribed by the books in my own study, that I have no opportunity of going any deeper into this affair at present; nor have I any interest on one side of the question or the other. As

the ancients were in possession of much valuable truth, and have delivered down to us the best elements, and some of the highest conclusions, in almost every science; it is a piece of justice due to them, from all men of letters, never to pronounce upon them from their own prejudices, but to obtain what light they can by a perusal of their writings; an employment which will be attended with more pleasure and satisfaction, and turn also to a much better account, than the taking up of an opinion upon trust from any modern writer whatsoever.

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